CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

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This document has been divided into a series of files for easier downloading from our web site.

Part 1 of 9

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Values, Health and Environmental Assessments

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Introduction

The purpose of what follows is to describe how values-based analysis can assist health professionals in contributing to environmental assessments. Explicit attention to values is often avoided by professionals engaged in environmental assessments. In our culture, values are widely thought to be personal, subjective and emotion laden. This view seems to imply that values are not a good foundation for building consensus or solving public policy issues. It is easy to think of what is personal, subjective or emotional as irrational.

This view is unfortunate because values form the framework for environmental assessment. Environmental assessment is defined on page 2-2 of Volume 1 as "a comprehensive and systematic process, designed to identify, analyse and evaluate the environmental effects of a project in a public and participatory manner. The goal is to anticipate and prevent adverse effects of projects by determining and evaluating the positive and negative impacts a project or action will have on our surroundings. A positive impact is one which adds something of value. A negative impact is one which destroys or interferes with something we value or something we consider to be of value. The purpose of an environmental assessment, then, is to ensure that a project will contribute something of value to those impacted.

What Values Are

The OED defines value as worth, desirability, utility. Things around us have value if they have these qualities. Good health is something virtually everyone desires or hopes for. It is so central to our welfare that it is often built into best wishes on important occasions. We desire health for its own sake because of the sense of wellbeing that comes simply from feeling well. We also desire health because of its importance to us in meeting our needs and realizing our goals and objectives. For this reason, good health is valued also because of its utility. Poor health has negative value because it interferes not simply with our ability to enjoy life but with our ability to earn a living or put food on the table or contribute in a meaningful way to family or community life.

The values we attach to things indicate their importance or significance to us. We value economic development when it creates value by facilitating our ability to realize our goals and aspirations or to live the kind of life to which we aspire. Economic development that resulted in an improved water supply, added educational opportunities or new jobs would have this character. We attach negative value to things that impede our ability to realize our goals and aspirations or destroys things which we value. Economic development that polluted a river thereby damaging a source of drinking water or food, or threatened a valued wilderness area, or threatened an endangered species would in the normal course of events be seen as have a negative value. Our values therefore provide the framework for evaluating the worth or merit of projects under assessment.

Values allow us to differentiate between costs and benefits. Costs are negative values. Benefits are positive values. A cost is anything that absorbs resources that could be used to achieve something else of value. A cost limits our ability to do other things. Benefits are things that are valued for their own sake or because they help us to realize our goals and objectives.

Finally, values play an essential role in decisions and choices. The purpose of an environmental assessment is to put people into a position where they can decide whether in their view a project will contribute something of value to their lives. Deciding whether a project should go ahead will therefore depend on how the values of the project's stakeholders are factored into the decision making process. One of the goals of this Handbook is to explain why health values should play a central role in this decision making process.

How then are values revealed? How do we identify values. How do we know what people's values really are? Answering this question is not nearly as difficult as it may first seem. This is because people's values are reflected in their preferences, priorities, goals, objectives, choices, and decisions. They are therefore reflected in and revealed by people's words and actions. This leads to an obvious conclusion. The best way to find out what people value is simply to ask them. This is why public participation is such an important part of the environmental assessment process. Public participation opens the door to the exploration of the values that the public believes should guide economic development decisions and choices.

Building Values into the Environmental Assessment Process

The World Health Organization has defined human health in terms of the capacity of people to realize their needs and aspirations. To assess the impact of a project on the health of those that are likely to be affected by it, an environmental assessment must therefore identify how a project under assessment will affect the capacity of its stakeholders to realize their needs and aspirations.

Identifying the health implications of a project for its stakeholders requires three things. First, it requires that those likely to be affected by a proposal under going environmental assessment are accurately identified. Second, it requires that the full range of values important to those likely to be affected by a project are taken into account in the assessment process. Third, it requires that the stakeholder values are properly understood.

Step one: stakeholder analysis

A stake is defined by the Oxford English Dictionary as an interest, something to be gained or lost or something at risk. The glossary at the end of Volume 1 of this Handbook describes a stakeholder as "any individual, organization or company that has an interest, financial or otherwise, in a project". A stakeholder can also be described as someone who stands to gain or lose directly from a project or someone who is put at risk by a project or the decision process that will determine whether and how a project will proceed and how it will be managed.

It is important early in the assessment process to acknowledge and then identify two quite different kinds of stakeholders: voluntary and involuntary. Every project under assessment will have voluntary stakeholders. These will be individuals, groups, organizations and institutions; employees, investors, governments and government departments who are free to decide whether or not to get involved in the project. For the most part, the involvement of voluntary stakeholders will be contractual in nature.

Genuinely voluntary contractual involvement requires informed choice. Informed choice requires, in turn, that voluntary stakeholders are fully informed about all aspects of a project that could reasonably be expected to affect in a material way their decision to become involved. This is a widely accepted requirement for establishing the existence of a contract in law. It is also a recognized requirement in investment regulations and other areas of business where ensuring informed choice is a recognized obligation.

One of the goals of an environmental assessment should therefore be to ensure that voluntary stakeholders have the information they need to make informed choices about their involvement. Information about potential health impacts on voluntary stakeholders is an example of the kind of information that will be required by voluntary stakeholders.

A conscientious effort should also be made to identify involuntary stakeholders and to identify carefully the nature of their stake in a project. An involuntary stake is created whenever a decision-making process exposes people to direct and significant risks which they would not willingly assume or about which they have no knowledge. When involuntary stakeholders are not identified, the costs and risks the project creates for those stakeholders are almost certain to be ignored. The effect is to transfer those costs from a project proponent to people who may have little to gain by way of benefits in return. Failure to require cleanup and land reclamation following mine closure or failure to assess the effects of the release of chemicals into a body of water on the fish on which a local population depends for food or tourism are both examples externalizing costs to involuntary stakeholders.

When a project's stakeholders are not carefully identified, important values that ought to be taken into account in the assessment process are likely to be ignored. This may then mean that a careful assessment of the impacts of a project on the health of its stakeholders cannot be accurately assessed.

Step two: identifying the full range of relevant values

Many people seem to think that the purpose of environmental assessment is to balance economic and environmental values. In contrast, a much wider range of values needs to be taken into account if the health impacts of projects under assessment are going to be properly understood. For example, a recent study of four Canadian resource extraction projects identified fifteen types of values the stakeholders of those projects wanted taken into account in the assessment process: aesthetic, educational, ecological, economic, environmental, health, legal, moral, personal preference, political, recreational, religious/spiritual, scientific, social, and subsistence values. (Note: these values are defined in Appendix I.)

Failure to identify the full range of values that stakeholders want taken into account in the decision making process can lead to serious over-simplification. One obvious casualty is health values. However, simplifying to a small number of categories may also mean that many values are indirectly connected to health for example, aesthetic, educational, recreational, moral, social, religious/spiritual and (for aboriginals for example) subsistence values. To ignore these values is to ignore issues that are central to human well-being and therefore central to human health (See p. 1-1 of Volume 1.)

Over-simplifying the range of values that stakeholders want to see taken into consideration in the assessment process has other effects as well. For example, it oversimplifies the interests of those who have a stake in the assessment process. As a result, individuals and groups whose interests in a project are quite difference will tend to be lumped together. A good example is aboriginal stakeholders. Frequently, those involved in the public discussion of environmental issues assume that aboriginal groups will be aligned with environmentalists and opposed to economic development. In fact, if careful identification of the values these two distinct groups typically bring to environmental assessments is undertaken, quite important differences are likely to emerge. (A careful reading of Chapter 5 of Volume 1 of this Handbook should confirm this observation.) For example, typically, aboriginal groups place a high priority on the social impacts of projects undergoing environmental assessment in which they have an interest. Religious/spiritual, subsistence and environmental values are also likely to be prominent. This may not be the case for environmental groups whose interests are likely to be more narrowly focused on just environmental and ecological values.

Finally, careful identification of the values of the stakeholders of projects under environmental assessment will ensure that the values of all stakeholders, including those who may be politically invisible will be taken into account. This is an important factor. For example, involuntary stakeholders may not even be aware that an environmental assessment is taking place. Yet their health may well be at risk. Values based analysis that is sensitive to the whole range of values that those likely to be affected by a project would like to see be taken into consideration in the decision-making process will help to ensure that no one's interests and concerns are left out of the picture.

Step three: understanding stakeholder values

The third requirement in building values based analysis into the environmental assessment process is ensuring that the values that those affected by a project want to be taken into account in planning and project evaluation are properly understood. Errors in the interpretation of the values of those affected by a project under assessment can be harmful and can generate serious resentment.

The language of values is in some respects quite simple. Essentially, values have just one of two functions. One of those functions is to identify the ends or the fundamental goals and objectives that define the stake or the interest that makes an individual, group or company a project stakeholder. These are best described as core values. One of the reasons for building health into environmental assessments is the belief that good health is a core value for virtually everyone. For this reason, it is important to take it into account in deciding on the merits of a project.

We also value things for their usefulness or utility in helping us to get where we want to go. Values of this sort are frequently described as use values. Water is valued for drinking. It is an essential for life and therefore has significant use value for all human beings. Water is also an important ingredient in many industrial processes for which it also has important use value as a means for accomplishing industrial objectives. And of course it is valued for many other reasons as well. Economic development is valued for the benefits it will bring, an improved standard of living, for example. It is because it is a means to the achievement of these benefits that development is valued. Development that generates benefits has a positive use value. Development that has harmful impacts has negative use value relative to the goals and objectives it interferes with.

[Note: I would like to put a diagram either as an appendix or integrated here into to the text. The purpose of the diagram is to illustrate the relation between core values and use values The relation between core and use values is illustrated in appendix two.

Identifying Core Values

Core values are the values that identify the fundamental goals, purposes objectives, principles, or ideals of a project's stakeholders. They are the values that identify things that are regarded as valuable for their own sake. For many people, health, family, or work will have core value. Protecting biological diversity or endangered species or a place of great natural beauty can also take on the character of a core value.

Core values reflect people's aspirations and are linked to their sense of well-being. Consequently, if the core values that define someone's interest or stake in a project are not respected, the project will be seen as damaging or harmful, or offensive. If a project does not interfere with people's core values, it will likely generate few if any objections. If a project contributes to the realization of core values, it will be supported.

Effective environmental assessment is possible only if the core values of those who have a stake in a project are carefully identified. This is less difficult than it may sound for two reasons. First, some of the core values will be defined by the legislation governing the assessment process. That is to say, environmental assessments are mandated with particular goals and objectives in mind. These will be core values for those responsible for carrying out the assessment. For example, the definition of "environmental assessment" on page 2-2 of Volume 1 indicates that one of the central objectives of an assessment is to ensure that the environmental effects of a project are known and evaluated before the project gets under way. A second core value is public participation.

The task of identifying core values is less difficult than it may sound for a second reason. For health professionals participating in an environmental assessment, the key core value is health. Impact on health is therefore the key issue and the central criterion for assessing the positive or negative value of a project.

Not all impacts on health will be direct impacts, however. And this does add a complication. The World Health Organization definition of health makes it clear that the impact of a project on health will depend in part on how it enhances or inhibits the capacity of stakeholders to meet their basic needs and realize their goals and aspirations. For this reason, assessing the core values that the various stakeholders bring to projects under assessment will have to be identified if a project's health impacts are to be understood.

Once again, identifying the values that stakeholders want taken into account in an assessment process is less complicated than it might seem on first glance. This is because, as a rule, in any given situation, the core values individual stakeholders or groups will bring to a development project will be relatively small in number. Further, quite a number of those values will be shared by all the stakeholders. And for the most part, those shared values will become obvious from public input.

For example, fishing will almost certainly be a core value for a community that relies on fishing as a basic source of nourishment. Protecting that resource will therefore have important direct and indirect health implications for them. For a community with high unemployment, job creation might well be a core value. A project that promised job creation would assist that community to achieve a core value or objective and thus have positive health implications for stakeholders, assuming of course that other important values were also respected, like for example, access to clean water.

Identifying Use Values

Core values identify the goals and objectives and other things of fundamental importance that define people's stake in a project. Goals and objectives have value, however, only if they are realizable. Hence core values always connect to questions about means: How do we get there? Can we get there? What resources are available to achieve our goals and objectives? What are the obstacles? Is it worth the effort? Anything that can help us get to where we want to go will have use value as a tool or means allowing us to accomplish what is important to us. Thus a proposal to build a saw mill in a remote community may well be supported because of the jobs it promises to create. Its job creation potential will be its use value for those wanting jobs. The logging needed to supply the saw mill will also have use value for the same reason. On the other hand, both the saw mill and the logging needed to support it will have also have negative value if the mill threatens to pollute a river that a community depends on for drinking water or for fishing.

Most common values an environmental assessment will deal with will be use or non-core values. Hence, assessing the use value or utility of a project from the perspective of its various stakeholders is a basic task of environmental assessments. The task of environmental assessment is to ensure that the development will be genuinely beneficial and that adverse impacts (negative use values) can be mitigated or adequately compensated for. Will the development generate employment? Will it support or undermine community development? Will it bring social problems that will be hard to deal with? Will it enhance or undermine the health of those affected by it? All of which is to say, will the project help people to realize their goals and aspirations or undermine their efforts in this regard?

There are three kinds of use or non-core values that play a role in environmental assessments. Distinguishing these three kinds of non-core values will be for many assessors the most difficult part of the process. Failure to recognize the different roles played by non-core values, on the other hand, can result in serious misunderstandings and serious conflict.

In main stream North American culture, instrumental values are the most easily recognized kind of non-core or use value. This is because one of the most common ways of determining the value of something is by determining its instrumental value. Everything we use to accomplish our goals and objectives has this kind of use value. Houses, cars, tools or all kinds, artefacts of all kinds are normally created or invented for their instrumental value. The more useful something is, the greater its instrumental value. The more important a goal or objective is, the greater the value of anything that is a means to achieving it. On the other hand, if an end or objective loses its value, everything that acquired value as a means for accomplishing that objective or end will lose its value as well. Thus, as gold loses its value, gold mines decline in value as well. Computers that are as little as a few years old are worth practically nothing because they have been replaced with computers that do much more much more efficiently. New technology makes old technology worthless.

Instrumental values have a number of characteristics. Two are particularly important. First, the instrumental value of things can almost always be monetized. That is to say, we can usually capture the instrumental value of things in dollar terms. We determine the costs of acquiring, or building or creating them and set these costs against their value for doing a particular job or accomplishing a particular objective. If the benefits exceed the cost measured this way, it is easy to think that the project should go ahead. For this reason, cost/benefit analysis will normally focus on the instrumental value of the things being analysed.

There is a second kind of use value at work in environmental assessment settings that are sometimes confused with instrumental values but are really quite different. Sometimes, we value things not because they are helpful in realizing core values but because they are essential. That is to say, in some cases, the value attached to things by stakeholders will derive from the fact that in the absence of that thing, something seen as having core value will become unattainable. Imagine, for example, that a tract of wilderness has qualities that are essential to the survival of a threatened species. There are no alternative habitats. If ensuring the survival of that species is a core value, then threatening the integrity of that tract of wilderness will threaten a core value directly. When this is the case, insensitivity to importance of the use value in question constitutes insensitivity or lack of concern for the core value it supports. Insensitivity to values of this sort can have health implications as well, though clearly it will not have these implications in every case. Projects that destroy things seen as essential components in a way of life, for example, will have damaging cultural impacts and indirect health implications.

One of the challenges of environmental assessment is to differentiate those things that stakeholders value for instrumental reasons as useful tools or means to accomplish things they think are important from things which are not simply useful but rather essential. The difficulty here lies in the fact that stakeholders themselves may not always recognize the difference. Sometimes, stakeholders will resist change believing something to be essential when it really is not. And sometimes people will agree to change without understanding the serious implications of that change for their way of life. Effective environmental assessments can go a long way to ensuring that these kinds of mistakes are not made. However, serious resistance to a project by stakeholders on the grounds of the harm that the project would cause if allowed to go ahead is an important indication that the values at stake are not just instrumental values.

Symbolic value is a third kind of use value. That is to say, people also attach value to things for their symbolic significance. Good examples in our culture are flags, or wedding rings, or objects associated with religious observance. What is less commonly recognized is the wide range of things and activities that can come to have symbolic value. Equally important it the fact that in our culture the symbolic significance of things is frequently unnoticed or ignored. A good example is the value we attach to jobs. Jobs have instrumental value. They provide income that allows people to provide for their families, for example. Seen from this perspective, their value can be determined by the income they generate. However, jobs can also acquire great symbolic significance. Seen from this perspective, their value is quite different. If a job has become invested with symbolic significance, for example, another job generating the same income will not have the same value. Thus, offering someone who has been a trapper all his life a job as a construction worker on a hydro electric dam project will likely not be accepted as a fair trade off by the trapper or his community. Those who are offering the trade-off may well fail to understand the resistance and chalk it up to bargaining or obstinacy. However, on the contrary, the resistance may reflect the fact that trapping for those involved has become a symbol of a way of life in which case those offering the trade-off will have misunderstood what is at stake for the trapper or his community or family.

Similarly, a forestry company may be tempted to measure the value of a tract of wilderness by the market value of the fibre it contains. A mining company may be tempted to measure the value of the same tract of land by reference to the market value of its mineral deposits it is thought to contain. In contrast, that same tract of land may have great symbolic significance for environmentalists and their supporters or for its aboriginal inhabitants, or for hunters or fishers. In each case, the core values whose importance the land symbolizes may well be different. What each of those assigning the land symbolic value will have in common, however, will be emotional resistance to an assessment process that measures value only in instrumental terms.

The reason for this is that symbolic values have characteristics that are quite different from instrumental values. Typically, things that have symbolic value are not replaceable in the way in which tools or instruments are replaceable. Their value cannot be measured or calculated in monetary terms in contrast to things whose value is instrumental in nature. Symbols are not instruments in this sense. A job that has taken on symbolic value for an individual or group of people cannot be replaced with just any other job generating the same income. A tract of land that has become identified as a national park cannot simply be replaced with another tract of land having similar characteristics. The value of a type of employment will be quite different for two people one of whom sees it as a source of income only and the other of whom sees it as symbolizing a way of life. Substitution or compensation works will normally work quite well for things whose value is purely instrumental. Its most likely effect will be to arouse anger and resentment on the part of people for whom it is a symbol. Symbols are not interchangeable in the way that things having only instrumental value are.

The reason for the difference lies in the way in which symbols symbolize core values. Symbols stand for core values. They may symbolize a way of life or particularly significant social relationships, a marriage for example, or environmental commitments, a commitment to protect endangered species, for example. In contrast, things whose value lies only in their utility are easily replaced when something that can do the job better comes along.

Symbols are particularly important for health impact assessment for two reasons. First, health itself is frequently invested with symbolic significance. A community may well measure its own health by the health of a nearby river or stream or lake even though the river or stream or lake is not a source of drinking water for example. Similarly, environmental destruction can symbolize insensitivity to health issues even though no direct damage to the health of anyone can be traced to the environmental impacts themselves. Happily the converse is true as well. Cleaning up a river or a lake or rehabilitating wild lands or parks can have impacts that go well beyond any results that could be predicted if only instrumental evaluation were in play.

Second, insensitive treatment of symbols is likely to be interpreted as a lack of concern or respect for the people for whom they are symbols. This in turn can have a damaging impact on the quality of life of those affected with subsequent implications for their health and welfare.

Two examples will help to illustrate these points. Traditionally, hydro electric development in northern Canada has been undertaken with little concern for its impact on aboriginal communities living in the north. More recently, sensitivity on the part of developers, including public utilities to environmental impacts has increased due in part to the requirement that large new developments must undergo environmental assessments. Indeed, one of the core values that now frequently attached to resource development is sustainable development. The problem for project developers, however, is to assess the impact of hydro electric projects from a sustainability perspective. For example, building dams that result in extensive flooding put mercury into the water that poisoning the fish. Aboriginal communities must then be advised not to use the fish as a source of food. Because environmental legislation no longer permits this kind of cost to be simply externalized, development proponents have concluded that sustainable development requires either substitution or compensation. One solution offered over the past two decades on at least three different occasions by companies committed to sustainable development has been to truck in frozen fish as a substitute.

This offer is reasonable if fishing is assessed from a purely instrumental perspective. That is to say, if the value of the fish no longer available to native fishers were measured from an instrumental perspective only. this solution would provide adequate compensation for the fishers affected. Indeed, some people might think that it was more than fair since it would mean that the people affected could maintain their diet without exerting any effort. However, for the aboriginal people involved, fishing symbolized a way of life. The activity and the food gathered was important because it symbolized a complex web of social and spiritual values. Frozen fish produced commercially could not have this kind of value. Hence, the offer devalued the core values of the people affected and caused anger and resentment.

Similar examples have been generated in recent years by environmentalists proposing that land be closed to logging and returned to wilderness status. Projects of this kind have obvious implications for loggers who face a loss of work if the project goes ahead. This is an obvious cost. The problem is to decide how to address it. One solution has been to propose that displaced loggers be guaranteed alternative forms of employment generating a similar income sometimes in their own community, and sometimes elsewhere. Loggers faced with proposals of this sort commonly respond with anger and resentment. This is because people living in small northern communities often see logging not simply as a job but rather as a symbol of a way of life to which they are strongly committed.

To summarize, values perform one of two functions. Core values identify things which identify the ends or the fundamental goals and objectives that define the stake or the interest that makes an individual, group or company a project stakeholdert. Use values, on the other hand identify things whose value derives from their usefulness in realizing goals and objectives of fundamental importance. Use values in turn fall into one of three categories. Some things will be valued for their value as tools or instruments useful in pursuing goals identified as having core value. Some things will be valued because in their absence, core values would not be realizable. Other things will acquire value as symbols. A sound environmental assessment will deal with each way of identifying the significance of environmental impacts on its own terms.

How to Build Values into the Environmental Assessment Process

Environmental assessment is a process involving five steps: project description (step 1); scoping (step 2); determining significance step 3); determining mitigation and follow-up (step 4); and recommendations regarding the project (step 5). Values based analysis in turn has three elements. Each step emphasizes one of these three elements.

Step 1: The first task in environmental assessment is to provide basic information about the project. The first task in values-based assessment is stakeholder identification. It is important, therefore, that the project description include the information that will be needed to identify the project's stakeholders. The project description should also contain the basic information stakeholders will need to identify the nature of their stake in the project. Second, unless the stakeholders are identified in the project description, it will be difficult to determine whether the project is likely to generate health concerns and the general nature of those concerns. Stakeholder identification at stage one does not require a more elaborate process than what is set out in Volume 1. What it does require is careful consideration of the factors set out in Table 2.1 at page 2-4 of Volume 1.

Once stakeholders have been identified, it is important to ensure that information in the project description is communicated in a way that allows the project's stakeholders to understand in general terms what they have at stake.

If the project description accomplishes these two goals, it will also ensure that the public generally knows who the stakeholders are and has the information it needs to build an adequate understanding of the nature of the project and its implications for the individuals, groups and communities that will be affected by it.

Step 2: Scoping builds on step 1. It requires identifying the biophysical and social environmental effects of a project that need to be assessed. Building a values component into this second stage of the assessment process will help to ensure that what is at stake for each stakeholder and stakeholder group is properly identified. This requires two things. First it will be important to identify the full range of values that stakeholders want to see taken into account in the assessment process. An environmental assessment is not likely to be effective if it identifies the relevant stakeholders but fails to consider the full range of stakeholder values likely to be affected. Ensuring that the full range of stakeholder values are considered will be particularly important if the indirect health impacts are to be accurately identified. For example, if aboriginal stakeholders are identified as stakeholders, but the values they think are important are not taken into account in the assessment process, impacts that may turn out to be vital to their health and welfare will simply be ignored. If impacts on social patterns are identified as important but impacts on recreational patterns or things of scientific value or political importance are deliberately or inadvertently ignored, things of value to some stakeholders will not be factored into the assessment process.

Second, scoping should include an assessment of stakeholder core values. Does the project intersect with goals and objectives or values that are of fundamental or central importance to the project's stakeholders? What are those goals and objectives and values? What is the nature of the impacts? Are the impacts direct or indirect?

How are core values identified? In some cases they will be obvious. Health is a core value. Hence identifying direct impacts on health ought to be a central objective of environmental assessment. It is the impact of a project on the core values of the projects stakeholders that will pose a challenge since these impacts will affect the health of stakeholders only indirectly. However, identifying indirect impacts on health will be crucial to an effective assessment since indirect impacts on health can alter the quality of life of stakeholders in significant ways.

One way to identify a project's impact on core values is to determine how a project is likely to affect the lives of its stakeholders. If significant changes are the likely result, it is almost certain that core values will be impacted. The challenge will then be to identify how the project will affect the capacity of those impacted to realize their core values. A second more direct way is simply to ask informed stakeholders whether a project raises fundamental concerns for them, what those concerns are, and why. It is the "why" that leads toward core values. Core values will be in play when strong emotional attachments are exhibited or answers to the question "Why is this important?" or "Why do you value this?" are no longer forthcoming. One indicator of a core value is the fact that when asked why something is important, the person being questioned can offer no reasons beyond sayings things like: " It simply is"; or "that is the way we have always done it"; or "I cannot say anything more than I already have"; or simply "It is a core value or something of fundamental or intrinsic importance for me".

Projects that do not put core values at stake are unlikely to arouse serious debate. It does not follow, of course, that core values are not in play just because a project has not generated serious debate. The lack of public concern is a reliable indicator only where a comprehensive project description has been undertaken and shared in a comprehensible form with all a project's stakeholders.

Step 3: Determining the significance of a project's impacts will benefit from careful identification and analysis of non-core or use values. How will the project under assessment impact on the ability of those affected to realize their core values? Will the project damage things seen to be of fundamental importance? Will it open the door to new and better ways to accomplish ends of fundamental importance to stakeholders or close doors that are currently open without putting something better in its place.

The objective here is to ensure that the impact on the ability or capacity of stakeholders to realize core values or live in accordance with their core values is carefully identified. Equally important, however, will be carefully identifying the nature of that impact. Will the project provide stakeholders with new and more effective ways to do the things that are important to them. Or will it reduce their capacity by removing or damaging valuable existing resources or practices on which people have come to rely? The focus here will be instrumental evaluation and the negative and positive impacts on things of instrumental value. Second, it will be important to determine whether the project is likely to put at risk something whose value is irreplaceable because without it, core values cannot be realized? Project impacts having this character will sometimes be obvious. A project that puts at risk an endangered species would be an example. Understanding the nature of an impact may be more complex. For people used to thinking about jobs from a purely utilitarian perspective, understanding the integral role of work related activities in a minority culture will be difficult and challenging. Failure to do so, however, may leave impacts with important indirect health related significance undetected.

Finally, identifying impacts having symbolic significance will be important. Once again, identifying things having symbolic value for stakeholders will often be challenging in part because it will not always be obvious even to the stakeholders involved what among the things important to them are important for their symbolic significance. A complicating factor will be the fact that some things having symbolic value will have instrumental value as well. Water and food are examples. Both have obvious instrumental value. Both can also come to be invested with symbolic value as well. Failing to capture both kinds of value in an Step 3 of the assessment have serious consequences for step 4.

Step 4: If values have been accurately factored into the first three steps of an environmental assessment, where mitigation is important and follow-up necessary will be greatly facilitated. Understanding how and why something is valued will make it easier to communicate and easier to find responses that are seen as appropriate by the stakeholders affected. If the value being disturbed is an instrumental value, compensation and/or substitution may well be appropriate and negotiating an appropriate solution (based on the determination of market value, for example) will offer in most situations a fair approach to achieving agreement. Mitigation will be the most obviously appropriate response where values integral to the achievement of core values are in play. Here substitution will likely not solve the problem. Neither will compensation unless project is seen by those affected as generating new opportunities or new values that the stakeholders come to see as equally attractive. What should be clear, however, is that inappropriate solutions when dealing with values of this nature might well have indirect but significant health implications.

Finally, responding to impacts having symbolic significance will require ingenuity and perseverance. Offering compensation, particularly monetary compensation based on calculations of market value, will almost always generate hostility and resentment, for example, offering market value for the land occupied by a cemetery or used as a traditional burial ground. Neither will substitution constitute an effective response. Providing people whose lives and social relationships have evolved from traditional ways of working the land with a factory job will not normally be perceived as fair or equitable. Offering to contribute a significant sum of money to a environmental cause as compensation for risking an endangered species is unlikely to be accepted as an appropriate solution to environmentalists or a community committed to environmental values. Solutions to these kinds of problems will have to be arrived at in quite different ways.

Concluding observations

These last comments may seem to some readers to expose a serious flaw with values-based environmental assessment. Identifying values for which traditional remedies like compensation are not appropriate is surely to create conflict not resolve it. And why should development be held up by symbolism or traditional lifestyles that may well be regarded as economically unsustainable in modern economies?

There are two answers to this kind of worry. First, ignoring symbolism and forcing significant cultural change is likely to have serious repercussion for the health of those affected. If protection and fostering health are core values for environmental assessment, then problems which cannot be mitigated, and for which substitution and compensation are inappropriate cannot be ignored. Secondly, direct and indirect impacts on core values can be negotiated. In some cases, negotiation will result in radically redesigned projects. In other cases, it will result in recommendations that projects not go ahead. People are capable of rethinking, reevaluating and restructuring their values. It is a process that is characteristic of all living cultures. Key to this process, however, is mutual respect. Dismissing people's values as not worthy of notice or attention is the ultimate form of disrespect and humiliation. Acknowledging core values and responding to them with respect is the foundation of effective problem solving. Effective problem solving with health as a core value ought to be the goal of effective environmental assessment.

Appendix I

VALUES THAT IMPACT ON ENVIRONMENTAL DIALOGUE:
A List with definitions

- Aesthetic: Values having to do with beauty.

- Ecological: Values of nature independent of human use or enjoyment. Eg., the value of the existence of a plant, an animal, a species or an ecosystem for its own sake, even if it is of no use or benefit to people.

- Economic: Values having to do with the generation of material wealth.

- Educational: Values having to do with the passing on of knowledge and of skill in the use of knowledge.

- Environmental: Values having to do with features of environment that are useful or enjoyable to humans or that support human life. Eg., the value of clean air and water, of quiet, of wildlife that people enjoy, of protection from dangerous solar radiation, etc.

- Health/safety: Values having to do with human physical wellbeing and safety.

- Legal: Values having to do with laws, rules and orders enforceable in a court. Eg. the value of acting within the law, of being law-abiding, or of deciding on the basis of legal principles.

- Moral: Values having to do with right and wrong, good and evil, and such virtues as justice and fairness.

- Personal: Values of a private or idiosyncratic character, such as sentimental attachments, individual tastes, personal preferences, etc.

- Political: Values having to do with legitimately authorized actions, procedures and decisions of governments and government agencies, and with efforts to influence governments and government agencies. Eg., the value of a government or government agency's acting within its mandate and jurisdiction, following proper procedures, acting in a fair and democratic manner, etc, or the value of a lobby group's acting in an effective and appropriate manner.

- Recreational: Values having to do with pastimes whose goals are relaxation, amusement, refreshment etc.

- Religious/spiritual: Values having to do with what is thought, understood or perceived to be sacred.

- Scientific: Values having to do with gaining knowledge through systematic observation and/or experimentation. Eg. the value of a forest or stream as a site for biological research.

- Social: Values having to do with human relationships such as families, friendships, communities, cultures and ways of life.

- Subsistence: Values having to do with provision of the necessaries of life outside of a cash economy.

References and Further Reading

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

DECEMBER 1999

This document has been divided into a series of files for easier downloading from our web site.

Part 2 of 9

The Risk Management Decision Making Process

Chapter B Contents

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Introduction

The purpose of risk management is to identify potential sources of harm and make decisions about appropriate actions concerning those sources. Proposed development projects may have a number of potential hazards. What are the risks and what needs to be done about them? Decisions concerning these issues are more workable if they are based on science, people and feasibility. The scientific evidence needs to be gathered making sure that people's concerns are being addressed and that the decisions are feasible in terms of available resources, technology, etc. Examples of decisions that can be made are: the type of advice to provide; how to communicate risks; mitigation strategies; and setting standards.

A formal risk assessment and risk management process helps risk managers focus their efforts on finding solutions and strategies for mitigating problems such as health hazards. A number of formal, structured processes often referred to as frameworks have been developed by organizations. Examples include the Risk Determination Framework developed by the Health Protection Branch (HPB) in the early 1990's, the Q850 standard developed by the Canadian Standards Association (CSA, 1997) and CODEX Alimentarious. The former focusses on making decisions concerning health risks while Q850 is designed to address a broader range of issues including health hazards, injury, property damage, and harm to the environment.

The HPB Risk Determination Framework is based on the following steps (Figure 1). Hazards are first identified, then risks estimated in the step called risk analysis. Then options for mitigating the risk are developed and analysed in the option evaluation phase. All of this is considered to be the risk assessment portion of the process. Subsequently, the risk management portion begins where the decision is made and implemented. Monitoring and evaluation of the strategy conducted and the entire process reviewed as new information comes to light.

There are several benefits in following risk decision making processes. They provide a systematic approach to decision making, help identify important considerations and fosters transparency and consequently accountability to the risk management decision making process. It also provides a common basis on which to address risks which is important in ensuring the fairness of the risk management decision making process across all projects and in facilitating collaboration, communication and negotiation among partners.

While there are a number of significant advantages, there are also some limitations to their utility. Data may be unavailable or limited yet decisions are required despite the uncertainty. Information may change with time. For example, mechanistic information about health impacts may come available after the EA had been completed and the project accepted. The framework is not meant to supply an automatic decision. Thus, subjective judgement still plays an important role. Rigorously adhering to a framework also does not automatically lead to consensus among stakeholders.

The HPB risk determination process is being revised into a new updated risk management framework. The new framework will provide greater emphasis on consultation and communication, explicitly address the benefits characterization and expand the context of risk to include social, cultural, economic and ethical considerations as well as determinants of health. Once the new framework has been finalized it will be accessible on the Health Canada website: http://www.hc-sc.gc.ca .

In this chapter, no particular framework will be presented. Rather the main concepts in risk assessment and risk management will be described.

Components of the Risk Management Process

The key components of the risk management process are: Communication, identifying the issues, characterizing risks and benefits, developing and assessing options, making and implementing decisions, and following up the results including monitoring.

Communication

Communication: The act of exchanging and sharing information, ideas and beliefs.

The consultation and communication process is becoming more widely recognized as an important component of the risk management process. Such efforts range from providing and obtaining information to total public involvement. Information exchange is useful for informing affected parties about risks and risk management decisions and to acquire scientific knowledge as well as to find out more about the concerns of affected parties. More active consultations can take place in which views are exchanged, an understanding reached on those views and even decisions made. The ultimate in participation by affected parties is total involvement from the beginning of the risk management process right through to making decisions, implementation, evaluation and follow-up monitoring. Here participants share in the responsibility and accountability for the risk management decisions. Chapter XXX in this handbook provides a more detailed description of the issues surrounding communication and methods for practising communications.

Benefits to relevant and quality communication strategies are building trust and improving confidence in risk management decision makers, learning about concerns, needs and attitudes, gathering information about the broader context of the risk and increasing acceptance and understanding of the risk management decisions. This is particularly relevant to the environmental assessment process which is to be done in a public and participatory manner. There is a need to involve those that are impacted since their perspectives and concerns may be different than those undertaking the science. Acknowledging these concerns can initiate ways of addressing the concerns.

Challenges faced in developing communication strategies are perceptions of risk, apathy and reactiveness. Distrust and low confidence hinder communication efforts. Establishing the right involvement including choosing representatives of key affected parties can be difficult. As well, well designed communication strategies can be costly and time consuming to implement.

Perception of Risk

Individuals' perceptions of risk are the results of their personal evaluation of the information they have about the risk. The public's perceptions of risk rarely reflects the estimated risk based on scientific evidence which can be disconcerting since perceptions can and have been known to drive government agendas and action. Perceived risk is not only based on the individual's knowledge of the science, but has been shown to also reflect the individual's values, beliefs and how much they dread the hazard. Trying to force perceived risk to resemble observed risk can be a futile task since the two measures of risk actually measure different things. Instead, perceived risk needs to be viewed as useful information in the risk management decision making process. By trying to understand the basis of perceptions; communication, education, and consultation will become more fruitful.

Communication is important throughout the risk management decision making process and will be highlighted throughout the following sections.

Identifying the Issues

Hazard: The adverse impact on health which can result from exposure to a substance. (Health Canada, 1997)

At the initial stage of the risk management process, problems are identified and a decision is made whether or not to proceed through the risk assessment/risk management process. Problems include substances, products and processes which have the potential for adversely affecting our health. More specific examples include pesticides, gases, radiation, air pollution, food additives, soil contamination, and water pollution. Health impacts include cancer, malformations, neurotoxicity, endocrine disruption, and respiratory illness.

Many methods are available for identifying hazards including:

- Measuring contaminant levels
- Reports of cases of adverse health effects
- Epidemiological and toxicological studies

Hazards do not only include bio-physical hazards but social, economic hazards as well. A population health approach includes all aspects of well-being, not just health and safety concerns. Recognizing that there are interactions among individual characteristics, social and economic factors and the physical environment, strategies for improving health must focus on the spectrum of influences called the determinants of health. These include employment and working conditions, income level and social status, education, social support networks, childhood care and experience, physical environment, personal health practices, individual capacity and coping skills, health services, gender and culture (Health Canada, 1997).

In addition to potential hazards there may also be potential benefits associated with the issue. For example, a development project may bring relative prosperity to an area with economic spin off benefits to its residents. Since decisions are often made by weighing risks and benefits, these benefits also need to be identified through a consultative process with affected parties.

Before proceeding in assessing and managing the risk, the problem should be put into context so that the problem is not considered in isolation of other effects and considerations which may play a role in decision making. Those who are affected may have concerns about lifestyle changes, changes in their standard of living and quality of life. The array of possible concerns is vast and thus it is important to focus in on those concerns of importance by consulting with the affected parties at the issue identification stage. In describing the context, special sub-populations at risk, eg., children, the aged, men and women should also be identified.

Once the context is described, a specific plan should then be developed for assessing and managing the risk following the broad guidance of the steps to be described in the following sections. The plan should include outlining the risk management goals, selecting the risk management team, beginning the development of a consultation and communication plan and a documentation plan. In particular, the scope of the decisions that are to be made should be determined to ensure that all subsequent analysis are relevant to the decisions to be made. This ensures an effective though efficient process is followed throughout. Again, participation of all affected and interested parties will aid in determining the scope of the decisions.

Risk: A measure of both the hazard to health from exposure to a substance, process or product and the probability of the hazard occurring. (Health Canada, 1997)

Characterizing Risks and Benefits

Characterizing risks and benefits takes a broad view of potential impacts which includes social, economic, ethical impacts as well as health and safety. Not only are risks described and analysed but potential benefits associated with the problem are analysed as well. For example, breast milk may contain potentially harmful contaminants but also has well documented benefits for developing infants.

The risk characterization process includes establishing risk based on health and safety, social, economic and other considerations, identifying affected populations, assessing exposure and estimating risk. Uncertainties in the available information need to be described and assessed. Affected parties are consulted as appropriate. It is particularly important that the risk and benefit characterization be focussed on the decisions to be made. Otherwise, more information may be collected than is required for making the decision, thus making the process unwieldy and unduly expensive.

This section will focus on the scientific characterization of risk.

Risk Characterization Methods

Epidemiology is the study of the distribution and determinants of health-related states or events in specified human populations and the application of this study to the control of health problems. (Health Canada, 1997)

Many methods are available for assessing health and safety risks. Human studies provide the most relevant information about human health risks. However limitations often preclude establishing cause and effect relationships. Cause and effect is best investigated using experiments in which the risk factor under study is the only factor changed in exposed and unexposed subjects. All other factors which could have potential impact on health are kept the same. In human studies, this is almost always impossible to accomplish due to the diversity in the human population. For example, an apparent effect could actually be due to another factor that is correlated with the factor under study, called a confounding factor. Clinical trials in which drug, surgical procedures or minor health effects are the closest to providing cause and effect information. However, these trials are unethical to use in determining many effects, such as toxic chemicals on humans.

Cause can only definitely be determined in a randomized experiment. Most epidemiology is observational. Thus a case for causality must be built up through the strength of the evidence, biological plausibility, consistency over a number of studies, by following subjects before and after exposure and by establishing a dose-response relationship.

Types of epidemiological studies include cohort studies in which a sample of subjects are followed over time with exposures measured and disease outcome recorded. Another common epidemiological study is the case-control study in which subjects with the disease outcome (cases) have exposure histories compared to those free of the disease (controls). Other types of epidemiological studies include cross-sectional and ecological studies. Epidemiological studies and their analysis are discussed in more detail in Chapter D on epidemiology.

Not all potential human health hazards are amenable to epidemiological investigation. For example, small increases in risk can be difficult to identify and the time involved in assessing chronic risks would be many years in a prospective study. Thus animal toxicology studies are often used as a surrogate.

Animal studies allow for testing of substances using mammalian models. Testing can be done before the chemical is available for humans. Studies can be done in a controlled environment in which only the factor under study is changed. However, rodents and other animals do not always have the same biological response mechanisms as humans since metabolism and pharmacokinetics could differ between species.

There are a number of types of animal bioassays. Acute studies expose subjects to high concentrations for short periods of time. Subchronic studies expose subjects daily for a portion of a lifetime, for example 90 days for mice and rats. In chronic studies, subjects are exposed daily for a lifetime (two years for mice and rats).

Other studies include metabolic and pharmacokinetic studies used to investigate absorption, distribution and elimination of the study compound. Teratology studies are used to study potential birth defects and reproductive studies are used to investigate reproductive effects possibly over a number of generations. There are also tests for genetic effects using bacteria, fungi, plant, insect and cultured mammalian cells and studies to investigate effects on the central and peripheral nervous systems.

In many programs such as under the Canadian Environmental Protection Act (CEPA): CEPA priority substances; CEPA new substances; and, the drinking water guideline program, the evaluation of risk evidence is based on the weight-of-evidence for carcinogenicity. For example under the weight-of-evidence scales for CEPA Priority Substances, substances are classified as carcinogenic to humans (Group I) if there is a causal carcinogenic relationship shown in human studies. Probably carcinogenic to humans (Group II), if there is significant evidence of carcinogenicity shown in animal studies but the epidemiological evidence is inadequate to establish causality; possible carcinogenic to humans (Group III) if the carcinogenic evidence is limited in both epidemiological and toxicological studies. Groups IV and V are likely not carcinogenic to humans and Group VI is unclassifiable with respect to carcinogenicity due to inadequate data.

Risk estimation

Risk is established quantitatively by estimating the exposure-response relationship then estimating exposure to determine if exposure is sufficient to present a risk.

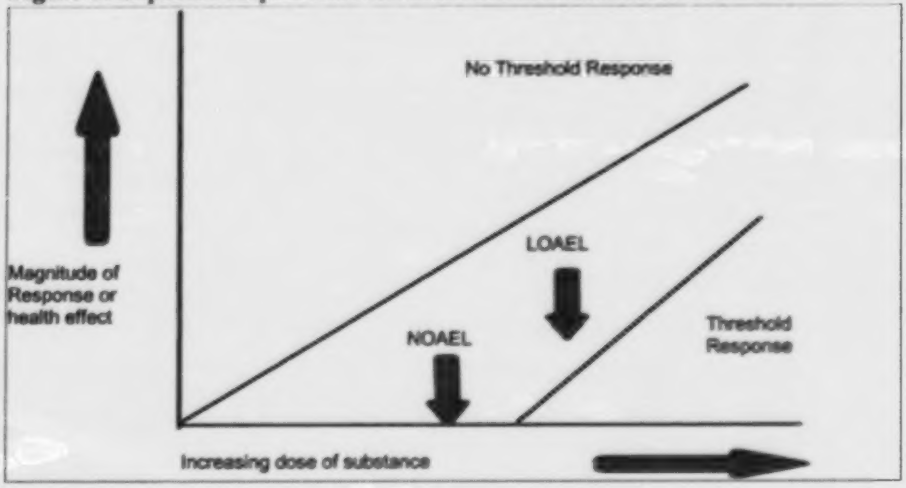
Exposure assessment is the study of the amount of a substance that comes into contact with a living system. Sources of exposure to chemical and physical agents includes occupations, drinking water, consumer products, food, transport and waste disposal. Major pathways of human exposure are air, water, soil and food.

Exposure assessment is the study of the amount of a substance that comes into contact with a living system.

In assessing exposure, the monitored group should be as representative of the population being studied as possible. If animal studies are being used to assess risk than the exposure route should match the human exposure routes. Assessments are conducted on a case by case basis and need to be tailored to the needs of the risk assessment.

Methodologies for assessing exposure include directly measuring levels while contact is occurring, predicting exposure using monitoring data and computer modelling and reconstructing past exposure using surveys, tissue biomarkers and other tools. Environmental monitoring measures amounts in an area or situation such as water and air, and personal monitoring helps establish levels that are individual experiences.

Figure 1: Exposure-response for threshold and non-threshold substances


No Threshold Response
Magnitude of Response or health effect
LOAEL
NOAEL
Threshold Response
Increasing dose of substance

To estimate risk, chemical agents are classified into one of two categories. For threshold substances, there is a level of exposure below which there is no risk. A reference dose, tolerable daily intake or acceptable daily intake is calculated and compared to typical exposure levels to determine risk. For non-threshold substances, any exposure no matter how small leads to an increase in risk. Examples of non-threshold type substances are genotoxic carcinogens such as ionizing radiation and certain types of chemicals, which cause cancer by damaging DNA and mutagens.

Risk estimates based on epidemiological data are often expressed as *disease incidence* or *mortality rates*—in other words, the number of new cases of disease or deaths in a population at risk during a specified time. One measure of disease incidence is the *cancer incidence rate*, the number of new cases of cancer that occur in a given period. For example, the estimated incidence rate of lung cancer in 1995 was

20 000 in the entire population of Canada, or about 1 in 1500. Incidence rates are used to calculate important measures of risk, such as *relative risk*.

Relative risk compares the incidence rate of disease or death in a group exposed to a specific agent with the corresponding rate in an unexposed group. In other words, it shows the likelihood of an exposed population contracting the disease or dying compared with the likelihood in an unexposed population.

Reference doses (or concentrations) for threshold substances are traditionally calculated by dividing a no observed adverse effect level (NOAEL) established in an animal bioassay by uncertainty factors to take into account uncertainties associated with the animal toxicology studies. Common default values are 10 for the animal to human extrapolation and 10 for susceptible human sub-populations. Other factors may cover using a LOAEL (lower observed adverse effect level) in place of a NOAEL, using subchronic studies in place of chronic studies, inadequacies in the database and developmental effects.

Reference Dose

$$RfD = \frac{NOAEL}{u_1*u_2*u_3}$$

where u_1, u_2 and u_3 are uncertainty factors

Limitations to the NOAEL approach are that the selection of the NOAEL depends on a statistical test which depends on the sample size of the dose groups. In addition, there are a limited number of dose groups so that the NOAEL may in fact be much lower than the actual threshold. A dose-response modelling approach has been proposed as an alternative from which the dose yielding an increase risk of 5% or 10% over background is used in place of the NOAEL. This approach is not used widely.

For non-threshold substances, the traditional approach is to estimate an exposure-response curve, than estimate the risk at typical environmental exposures. However, in most cases, exposure at small levels usually encountered in the environment are not observed in animal bioassay studies nor in occupational epidemiological studies. Thus, the portion of the dose-response curve, at the low environmental levels is unknown, making extrapolating to low doses highly uncertain. Various methods have been proposed to estimate risk at low levels including the linearized multistage model and model free extrapolation.

Uncertainty

In characterizing risks and benefits, the uncertainties and assumptions should be described and quantified where possible. Uncertainties in extrapolating from animal toxicology studies include high doses in animal studies versus low human exposures and differences among species. Using a different route of exposure instead of the target route leads to uncertainty as well as using subchronic studies for examining chronic effects.

Uncertainties in human epidemiological studies are found in historical exposure estimation when measuring technology has changed over time or reliable historical levels are unavailable. Even exposure estimation for prospective studies can be uncertain when collecting the information requiring a high degree of cooperation from subjects or when the measurement instruments are complex, eg., dietary surveys. In addition, disease may have diagnostic errors. Human epidemiology studies are often based on occupational groups who are exposed to higher levels than the general population and susceptibility, exposure patterns and demographics vary among individuals.

Uncertainty is dealt with by invoking conservative assumptions. Some typical assumption made are that humans are as sensitive as the most sensitive animals, that the dose-response curve for DNA reactive toxicants is linear in low dose regions, that there is no threshold for genotoxicity, consideration is given to high exposure groups, risk estimates for non-threshold toxicants usually incorporate upper confidence limits, and uncertainty factors are used in establishing guidelines for threshold effects.

Uncertainty is quantified for risk and exposure estimates using probabilistic assessment. Distributions are developed using data or subjective information for each input parameter. Input distributions are sampled using Monte Carlo techniques and the results entered into the exposure or risk equation to obtain one simulated point. This procedure is repeated a large number of times, perhaps 5,000 or more until a risk or exposure distribution is built up.

Probabilistic assessment yields more comprehensive information about the risk or exposure estimate, which are traditionally presented as a single point estimate. The resulting range of estimates allows risk managers to: put the point estimates into better perspective by displaying other characteristics of the distribution such a percentiles, modes and medians; to identify the impact of uncertainties in each of the input factors; and enable more realistic comparisons among several exposures or risks. However, there are limitations as well. Input distributions are often highly subjective and complicated to interpret. Training may be required to conduct the analysis as well as to educate others in its interpretation. This analysis does not eliminate the need for professional judgement and carries a potential for errors in assumption. It is also important to distinguish between variability, that is the inherent variability associated with a factor such as body weight, and true uncertainty which refers to lack of knowledge.

Developing and Assessing Options

A number of broad classes of options are available for managing risks and can be regulatory or non-regulatory in nature. Non-regulatory options include: advisories where information is provided to promote risk avoidance; new technologies developed to reduce risk, for example child proof lighters; and, economic where financial incentives and disincentives are used to reduce risk. Voluntary compliance strategies and guidelines are also non-regulatory options.

Considerations for evaluating options include hazards and the risks involved, uncertainties in the risk estimation, health benefits associated with the hazard, public perception of risk, acceptability of the risk, characteristics of the option (including technical feasibility, potential effectiveness and environmental, economic and social impacts) and the viewpoint involved (e.g. individual or societal). Viewpoint is particularly important when those who bear the risks do not obtain the benefits.

A simple strategy for evaluating options would be to choose the one which leads to the greatest reduction in risk. Another strategy is to select the technology which leads to the greatest reduction in risk. However, there are often a number of other factors which impact on the decision so that more complex methods are desirable. For example costs of mitigation often play a role. Cost-effectiveness analyses compare costs of reducing exposure by one unit. Benefit-cost analyses compare costs of mitigation versus benefits incurred. There are limitations and uncertainties associated with this procedure. For example, costs are often easier to predict than assessing intangible benefits such as health and the quality of life.

Things to Consider When Analysing Options

Nature of the hazard and the associated risk	Many factors may be considered, such as the level and probability of exposure to the hazard, the nature and size of the population(s) at risk, interactions of the hazard with other hazards and the magnitude of the risk relative to other similar risks.
Benefits associated with the hazard	Hazards may be weighed against associated benefits. For example, although there may be some associated health effects, chlorine is often used to kill microbes in water and in public swimming pools because of its effectiveness.
Public perception of risk	Risk perception refers to the way in which individuals intuitively see and judge risks. For example, people often overestimate the likelihood of unlikely events, such as airplane accidents, and underestimate the likelihood of more common events, such as heart disease or stroke.
Risk acceptability	Acceptable risk is one that is so small, whose consequences are so slight or whose associated benefits (perceived or real) are so great that persons or groups in society are willing to take or be subjected to that risk.
Characteristics of the potential risk management option	Policies and actions intended to reduce risks may result in other risks or potential health, environmental, economic and social impacts. For example, although automobile air bags have reduced traffic fatalities, some people have died from injuries caused by the deployment of the air bag during a traffic accidents.

Source: Health Canada (1997) "Health and Environment - Partners for Life"

When appropriate, it is advisable for the proponent to present a number of options so that comparisons among mitigation strategies can be made. For example, in the recent decision by the Panel reviewing the High Level Nuclear Waste Disposal Concept, the Panel indicated that comparisons with alternative options to the concept of burying the waste are necessary to help the public understand better the issues and relative risk.

Making and Implementing Decisions

In making the decision, responsibility and accountability needs to be established. This should have been done in the planning phase of the risk management process. Decisions can also be made through deliberation with stakeholders, the public and other affected parties. In the latter case, those participating are jointly responsible and accountable for the decisions. Consultation is particularly important for strategies involving partnerships and community action programs.

Once the decision is made, it should be communicated to affected parties and an implementation plan developed. Roles and responsibilities are assigned, the objectives of the strategy formalized, timeliness and milestones established, a consultation and communication plan developed and resources allocated.

The strategy and implementation should be evaluated to be sure that risk is mitigated as expected. Monitoring and surveillance program are designed and implemented, performance indicators measured and quality control and quality assurance systems put in place.

Risk management decisions need to be reviewed regularly. New toxicological or epidemiological evidence could lead to changes in the risk characterization. Monitoring may also indicate unexpected changes in status which may need to be investigated. Review could lead to a revisiting of the risk/benefit characterization, options analysis and decisions.

Following up the Results

Agencies that implement risk management strategies frequently monitor and evaluate them to determine their effectiveness. Although it is desirable to measure different impacts, those related to physical health effects are often easier to measure than those related to non-physical health effects, such as stress.

Strategies may be evaluated both qualitatively and quantitatively. For example, human exposure to contaminants in water or food may be monitored by analysing concentrations of the contaminant in human tissues or body fluids both before and after the risk management strategy is implemented. Evaluations may also involve epidemiological studies, surveillance (monitoring the incidence of disease, injury, product failure, etc., following implementation of the risk management strategy) and formal and informal gathering of information from stakeholders.

New information may lead to a review of any step in the risk assessment and risk management process. This review may occur at any point in time and is typically undertaken by the organization responsible for risk management. Review may lead to a reconsideration and revision of any previous step in the risk assessment and risk management process.

Difficulties and Challenges

The process needs to be general enough so that it an be applied to a wide range of environmental assessment projects. At the same time, it needs to provide enough guidance to the process so that all the essential elements of the process are addressed. This can be done by having specific guidelines associated with each general step of the framework. For example, guidelines for exposure assessments could be provided in the risk estimation phase.

As the social and regulatory climate changes, different issues must be considered when assessing and managing risks. Frameworks need to be reviewed to ensure that these considerations are being addressed. As mentioned in Section 3.1, HPB of HC is currently updating their framework to reflect greater emphasis on the participation of stakeholders, partners, and the general public.

Gathering the information and consulting with those impacted in order to satisfy the process requirements may seem time consuming especially since they are designed to span a range of ideas and options. In the end, time put into this structured approach may actually save time since it likely will lead to more complete information and actually reduce the number of times an assessment needs to be revisited before a decision concerning the viability of the project is made.

Conclusions

A structure decision making process can help us structure and systematize the collection of information for environmental assessments. They need to be updated periodically as the social and regulatory climates change. There are limitations to their use but nevertheless has the potential to yield more complete, transparent information on which to base decisions.

Suggested Readings and Resources

Health Canada. *Health and the Environment, Partners for Life* Minister of Public Works and Government Services Canada, 1997.

Health Canada. *Health Risk Determination.* Health Protection Branch, Ottawa, 1993.

Canadian Standards Association (1997) *Risk Management: Guideline for Decision-Makers. A National Standard of Canada*. CAN/CSA-Q850-97. 54 pages.

United States National Research Council (US NRC) (1997) *Understanding Risk: Informing Decisions in a Democratic Society*. National Academy Press, Washington, D.C.

(1997) U.S. Presidential/Congressional Commission on Risk Assessment and Risk Management.

Health Canada website - http://www.hc-sc.gc.ca

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

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This document has been divided into a series of files for easier downloading from our web site.

Part 3 of 9

Social Impact Assessment Approaches in Environmental Impact Assessment Protocols: A Social Science Perspective

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Introduction

One of the earliest social impact assessment (SIA) studies was undertaken by the Marquis de Condorcet in 1775 when he anticipated and evaluated social and health-related impacts of a proposed canal that was to join two French towns (cf. Becker 1997). For the sake of the present discussion, however, the period of main interest for the development of SIA concepts and methodologies —as applied to environmental impact assessment (EIA)—, is usually acknowledged in North America as the early 1970's. During this period, two important events (the US National Environmental Policy Act, and the inauguration of the Canadian Environmental Assessment and Review Process) provided the main impetus to integrate into EIAs concerns over the cultural and social impacts of development projects (Burdge and Vanclay 1995; Craig 1990).

In the context of EIAs, the advisory role of health professionals is often to make sure that negative health effects are evaluated when possible, that adequate mitigation measures and monitoring programs are suggested and that negative impacts are balanced with potential induced positive health impacts such as a greater infrastructure for emergency (search and rescue) operations, an additional health care facility on the land, economic spin-offs and the reduction of transfer payments, an increase of the labor-market active population and a greater spending power for the workers.

However, to maximize their input, health professionals must be able to participate early in all phases of environmental evaluations, from the writing up of the guidelines for the environmental studies to the review of the environmental impact assessments once they are completed.

Because social impact assessments are one of the main sources of health data in environmental impact assessment reports, the objective of this section is to provide a realistic overview of what a SIA usually consists of, and of which methods are typically used by social science consultants when estimating impacts of development projects. It is hoped that this will help health professionals understand the usefulness and limits of SIAs and facilitate their interpretation of the data covered.

What exactly is a social impact assessment, what data can be found and what should not be expected of an SIA? This chapter first discusses the purpose of SIAs, the types of questions addressed and the strategies used to address the questions and get the appropriate information. This is followed by a discussion of the usual elements found in SIAs as well as the type of expertise necessary, and potential health considerations that should be kept in mind by health practitioners who are likely to be involved in the environmental impact assessment process as either reviewers or collaborators.

Scope of Social Impact Assessment

What are the Main Characteristics of Social Impact Assessments?

The purpose of SIAs is to address potential impacts of development projects, to describe the social context in which the projects are to be inserted, and to predict social change that can be related to the projects (cf. ICGP 1994).

The main objective of SIA is to predict direct and indirect repercussions of a proposed project on the social environment closest to the area in which implementation will take place. In the case of EIA, the definition of impacted communities is usually based on the extent of predicted spatial coverage of impacts on the physical environment, and SIAs are often limited by this definition. In theory, SIA should also look at the effects on other communities indirectly affected by the project (e.g. those that benefit from direct or indirect economic spin-offs), however the focus is normally narrowed down to the communities where the main part of the development is undertaken. For example, if a resource development project is to operate in a remote area, the communities closest to the work site are usually the focus of the SIA, even though other communities considerably further away can also be affected by related infrastructure development (e.g. construction of a transformation plant, shipping and transportation logistics, long-distance commuting labor, and so on). In a limited sense, EIAs do take into account socio-economic impacts on communities not directly affected by the projects, but this is done through an economic evaluation where geographical coverage is considerably larger; covering most places where direct and indirect costs and benefits are incurred through the different project components.

One of the main components of the SIA process is the description, of the social environment within which the project will be inserted. This includes the political, social, cultural, historical (in terms of past experiences with development projects, for instance) and economic (labor and market considerations) dimensions, and some inferences on social carrying capacity (e.g. the limits pertaining to population size or characteristic group composition that given resources or services in a community can support without destruction of the social fabric). Once this context has been described, then projections can be made of potential impacts. This is why SIA reports are often divided in two parts: first, a description of the milieu, then an evaluation of potential repercussions of the project and proposed mitigation and monitoring measures.

SIA focuses on various social and community indicators (see Social and Community Indicators of this chapter). However, the exact nature of the indicators taken into account (either quantitatively or qualitatively) varies from one evaluation to the other because SIA is dependent on a number of external elements such as: province or state regulations; the EIA terms of reference; financing available for the evaluation; personal expertise and familiarity of the evaluator with SIA literature; as well as, the nature of the project itself.

In EIAs, SIA is interpreted strictly as an evaluation of prospective impacts, both negative and positive, of a development project. However, as opposed to EIAs, SIAs usually try to integrate and articulate the perspectives held by the various stakeholders involved.

Essentially, SIA describes what types of effects will likely be felt in the communities affected, identifying those groups at risk or at benefit and, when possible, the extent of the impacts (time frame, degree of pervasiveness, proximity indicators...). The fact that SIAs are predictive (as opposed to outcome evaluations based on monitoring activities) is also one of their major limits, and must be kept in mind. For instance, what in a pre-project evaluation could be predicted as a major impact (negative or positive) can, once the project is implemented and monitoring activities are set up, turn out to be a minor impact or even lead to unpredictable effects.

A dominant pattern of SIA work is the premise that the different perspectives held by stakeholders concerning a proposed project are all valid and valuable. In this sense, the SIAs often seek to identify and understand the different points of view, in order to better identify potential problems and to provide some insight into the community's receptivity to and concerns regarding the project.

The SIA must take into account both positive and negative outcomes (not measured in terms of dollars but rather in qualitative social changes). When the analysis is complete, evaluators are sometimes asked to express somewhat quantitatively the potential impacts in terms, for instance, of minor, major or null disturbances. For some, the idea is to eventually be able to weigh costs and benefits, which is perilous and -often-useless because it is extremely difficult to do and value-laden (i.e. whatever the result, many will not agree on the scale of the projected impacts). For others, this exercise must serve essentially as a summary, or a reminder, of the necessary mitigation, compensation or monitoring measures.

In principle, SIAs are undertaken by external evaluators. Their assessments can be characterized as being highly dependent on the collaborations and input they seek from the various stakeholders associated with the proposed projects.

In principle, SIA lends itself well to, and most often does use, a collaborative approach because evaluators depend greatly on inside knowledge of affected community members to help them predict the potential impacts. This can however be done in different ways. For instance, open-ended interviews can help the people impacted express their specific concerns, and directive interviews can test some impact hypotheses. Also, in some cases, a method which can be used is to present an initial draft of the SIA conclusions to the impacted communities to seek further input, to test evaluation acceptancy or to validate the projections. However, this type of collaboration has its limits, because the impacted community does not often have the final word on the final version of the SIA, and most often the many people met during the SIA work are not in a position to respond to the draft SIA.

The SIA is most often conducted by specialists not related to the project proponents. This, in principle, enhances evaluation credibility by ensuring that an independent point of view is provided. However, in reality a certain number of elements can weed out compromising conclusions of the SIA. The two most important are: impact evaluation is often mandated to a private firm, which hires the specialist staff needed. This provides a first filter for the SIA conclusions. A second filter is added by the project promoter who gets to read and provide the final approval for the EIA report, essentially because it is the promoter who is required to submit an EIA. This is a fundamental characteristic of all EIA, and must be kept in mind by its users.

What Should not be Expected from Social Impact Assessments?

In the very specific context of an EIA, the purpose of SIA is rather limited and cannot be seen as a panacea for every social assessment related need. Thus, SIAs cannot be considered as information sources on the proposed projects, they do not focus on the promoter's cultural reality, nor are they directly concerned with following-up on the implementation or monitoring phases of the proposed projects.

Per se, the SIA is not question focused; its objective is not to answer questions or concerns of the impacted communities, nor to address the project promoter's objective to facilitate project acceptancy. In reality however, questions from both sides are dealt with by the social scientists who sometimes act as information or message relays between the impacted communities, the promoters, and other evaluators (e.g. those working on assessing biophysical environment aspects of impact studies, for instance). This position is not always easy for the evaluators because SIA most often starts before the project design is completed. Moreover, SIA evaluators do not have unlimited access to the promoter's information or data. In fact, the promoters usually consider informing the communities as their own responsibility. Yet, because this information does not make it to everybody in the communities, the social scientists sometimes have to describe what they know of the project; how else could they ask people to participate in a SIA and provide informed opinions? In sum, although SIA evaluators are not formally asked to play an advocacy role to ensure effectiveness of the decision-making processes, their input and contacts with the population can assist the relay of information between the promoters and the communities.

The focus of a SIA is not centered on the validity of the proposed program or project itself, nor on its culture. This is usually considered as a black box topic by the evaluators. The idea is thus not to evaluate the project promoters. In some cases, however, some insight is given in SIA on the social interactions of the project workers and promoters, and their possible relations with the impacted communities. On the other hand, many evaluations mention an ethnographic focus in their methodology, because they try to provide a good insight of the impacted communities' culture - sometimes for the benefit of the promoters-, but also to understand more clearly and predict where hidden and visible social effects of the project will be felt. However, in this latter case, it is not the purpose of the SIAs that are ethnographic, but rather the methods employed.

In principle, evaluating whether a project is implemented the way it is supposed to be remains separate from the EIA study. Although this type of evaluation might be useful for evaluating socio-political impacts, SIA is not an analysis of the interaction between project promoters and impacted communities. It is also not an analysis of the way project design and implementation develops, nor the way impacted communities get to voice their concerns (i.e. it is not a decision-management process analysis).

Thus, the objective of SIA is not to see to what extent the program or project was implemented as designed, nor what problems come up during implementation and need to be looked at. However, a good evaluation will undertake a review of related studies and will predict potential problems, i.e. as in the case of an ethnographic focus. Nonetheless, the SIA finishes before the project starts; then other mechanisms come into play (such as those designed for monitoring purposes).

Routine data (indicator follow-up, social, physical, biological, or other) is not collected and analyzed on an on-going basis in SIA. External consultants are most often required to provide a one-shot evaluation of potential impacts (positive and negative) and provide some insight on indicators that should be monitored. But that's it. If monitoring occurs during a project's definition or during its negotiation phase, the data is usually collected either by the project promoter's public relations department, or by representatives of the impacted community (e.g. by their consultants or negotiators or special interest groups when they have the resources and the impetus necessary), or through regular activities of governmental agencies and departments.

Which Elements are Described in Social Impact Assessments?

Unless formally required in the environmental impact directives, the following elements can usually be found described or referred to in an SIA (cf. Branch et al. 1984, Finsterbush 1985, Bowles 1981).

Physical environment

In regard to the physical environment, the three fundamental elements to be considered in view of potential disturbances and the need to develop preservation or mitigation measures are archaeological and historical sites, important landmarks, and land use and occupancy patterns.

Archaeological and historical sites: Surveys are usually undertaken by archaeologists. Their objective is to identify archaeological or historical sites, remains or artifacts that may be subject to disturbances due to the proposed project activities. Once they have identified and officially catalogued these sites, safeguard measures or exploratory as well as salvage excavations can be undertaken in accordance with provincial or state regulations.

Through their essential input on historical land use and occupancy patterns, social scientists can help pinpoint areas of interest and document types of past activities associated with these areas, values attributed to these places of interest, and community feelings regarding the need to protect the sites or even correct disturbances due to past development activities.

There are usually few health aspects directly related to this work, most community concerns and issues being of a socio-cultural nature (e.g. values, equity and empowerment issues, etc.). However, if important value-laden sites are not well identified and disturbed by the project, in some contexts popular hindsight associations might be made later on between taboo breaches, for instance, and apparent or perceived illness episodes.

Important Landmarks: The most often examined landscape parameters are visual impacts and transportation infrastructure. These are usually assessed by either geographers, landscape planners or urbanists. When they are called upon, most of their work, however, is usually centered around designing mitigation or compensation measures. Also, because some landmarks of specific interest might need to be preserved, a highlight of the main features of the impacted areas is usually undertaken in an EIA.

As for noise levels or odor emissions, these elements are rarely extensively discussed in SIAs, unless they are described as potential threats during pre-evaluation scoping procedures. When they are mentioned in SIAs, it is most often because the impacted communities have expressed some concerns around these issues.

Because of their academic background and of their knowledge of local communities, social scientists can help identify where, when and why potential visual impacts as well as noise or odor pollution can become more than a simple disturbance and contribute to emphasizing perceived or actual risks.

Also, through their work on land use and occupancy patterns, social scientists can identify valued landmarks and the perceived limits to developing or altering existing landmarks or transportation routes. Through community consultations, they can also help design more socially acceptable mitigation measures.

Some areas might hold invaluable resources for local ethnomedicinal uses. Although knowledge on collection, preparation and use methods are seldomly shared with outsiders, if queried local experts will often mention the need to preserve these resources and those areas of interest.

Noise and odor pollution can lead to different physical health problems or induce psychological reactions. Evaluation of the extent of these potential problems is however difficult, and usually not mentioned in SIAs. If experts are asked to provide likely noise or odor estimates and evaluate potential impacts for the EIA, then these analyses are usually published in a report separate from the SIA. If extensive modelizations are also undertaken around the worksite, then this is part of the monitoring process and not included in the SIA.

Different disturbances can also lead to injury or accidents. This is the case, for example, with sudden noises (such as with low level flying, or blasting) or inadequate signalization where traditional transportation routes or corridors can be disturbed by the project developments and activities.

Land use and occupancy patterns: Often done by social scientists, land use and occupancy surveys essentially serve to identify who uses the lands and resources potentially affected by the proposed project, to clarify identity, environmental stewardship and ownership issues concerning these lands, as well as to document the different types and intensity of resource use. Typically, these studies provide a historical perspective of the evolution of land use and occupancy in the area.

This is essentially a descriptive part of the SIA, but different data expressed herein serve directly to evaluate health effects related to the proposed project components, such as impacts on nutrition or recreation. Essentially, this can be calculated from the perspective of diminished access to resources and lands as well as resource depletion.

Social and Community Indicators

In regard to the human environment, the main indicators assessed relate to social organization, public services and utilities, sociodemographic characteristics of the impacted communities, economy and health. However, headings and internal organization of the SIA reports vary in detail from one evaluation to the other.

Demography: Ideally, describing and analyzing demographic data should be done by demographers who have the ability and knowledge necessary to prepare simulations which can be useful when predicting long term impacts of development projects.

However, in SIAs demographic descriptions are often static and done either by a social scientist or, frequently, by economists because they also need this data to modelize their economic simulations. In some cases also, just about anybody available in the consulting firm can look up and use official census data. Needless to say, in this latter case, very little insight is provided in the SIA on what the demographics suggest.

The most important demographic data to look for in an SIA are sex ratios, age pyramids, in- and out-migration mobility patterns. These data are used to simulate economic impacts, to define the characteristics of the potential local workforce, and to evaluate some impacts of a transient or new in-migration workforce.

The main health issues to keep in mind are the possible pressure of in-migration on public utilities as well as on access to health services available in neighboring communities. Increased transportation infrastructures to isolated communities can also, in some cases, lead to out-migration of local residents.

Polity: This is usually a domain of the social sciences. Polity refers to public administration and community infrastructures, including formal and informal organizations, community services, housing, transportation, utilities, and so on. The objective of the SIA in respect to polity is to evaluate the strain a proposed project can have on local access to community services, for instance because of demographic pressure from migrant workers on the availability of housing, community services and equipment, and store supplies. SIAs also seek to predict the capacity of the public administration to adequately deal with issues that might arise between the project staff and local inhabitants.

Transportation and safety issues must be kept in mind when examining changes to local transportation infrastructure. Public hygiene and health should also be taken into account in regard to the carrying capacity of existing utilities and to potential impacts on basic resources such as potable water.

Economy: Definitely the grounds of economists, economic impact assessment is very often integrated in the SIA reports. Economic evaluations in SIA do not cover the profitability of the project, but rather its potential effects on the general economy (jobs created, taxes paid, services and goods bought, and so on). The main elements described in regard to impacted communities are employment and manpower, activity sectors, businesses, income and expenditures. In the impact assessment section per se, the direct and indirect economic benefits of the projects are often well described. However, negative economic impacts on neighboring communities are either forgotten or occupy considerably less space. This is an important aspect of economic valuations which are based on the premise that the projects being essentially driven by economic imperatives, impacts are necessarily positive. Moreover, economists rarely have direct access to knowledge on local dynamics and thus are often unable to identify local economic resistance or promotion factors. In some SIAs, indirect economic impacts will be calculated, on property value for instance, as will other direct impacts, such as on local purchase power and spending patterns, but this is usually done when the economists are able to secure input from the social scientists.

There is a fundamental difference between the evaluation of economic spin-offs and cost-benefit studies. Economic spin-offs are always considered positive when undertaken in SIAs because the level of economic activity is increased every time money is spent whether to build a factory, to clean-up a river bank or to hire workers. As for cost-benefit or cost-efficiency studies between options, the focus is rather put on evaluating the distribution of impacts, i.e. who wins versus who loses.

Concerning employment, social scientists will often generate data on equity considerations in the labor recruitment process for the project, or potential personnel turnover rate problems by considering local expectancies, needs, qualifications, education levels and customs. They might also bring up other related issues such as potential "skimming effects" of jobs offered by the project (i.e. new development projects often drain some of the leaders and some of the most qualified workers from neighboring communities, thus generating indirect social impacts).

Because they are more likely than economists to have access to local data concerning informal economy, social scientists can help document project-related externalities, such as revenue losses incurred due to diminished resources or reduced access, and can pinpoint those groups at risk of having to bear these losses.

Increased spending power or diminished access to natural resources can impact positively or negatively quality of life indicators or generate nutritional changes.

Education: Education data is compiled by the social scientists or the economists essentially in order to determine the potential labor basin and skilled personnel locally available. This data is used to evaluate potential employment creation benefits and to determine the need or possibility of setting-up specific training programs. There are usually few health aspects directly related to this part of the SIAs, as increased training and education are usually viewed positively when equitable.

Health: Birley and Peralta (1995) group health hazards of development projects into five categories: communicable diseases, noncommunicable diseases, malnutrition, injuries, and mental disorders. Although all these can sometimesd be found described in EIAs, health hazards or health risks are typically analyzed in a number of different ways. Usually, the source of risk defines where specific health effects are discussed and evaluated. For instance, toxicological analyses regarding potential contamination through drinking water, airborne gazes or particles or contamination of the foodchain can be found in the biophysical impact assessment reports. In turn, impacts that are related to human efforts, interactions, choice, values or orientations can be found in the SIAs.

In SIAs, description of health issues calls upon a number of indicators, depending on which can be found detailing data specific to the neighboring communities. In sum, just about any numbers can be presented concerning mortality and morbidity rates. Typically, about the only data that are actually summarily discussed are alcohol and drug abuse, or sexually transmitted diseases (STDs) —usually laconically mentioned as a potential problem due to an influx of lonely migrant workers.

The description of health data can be useful to health professionals to put the impact assessments in context or to propose, when possible, adequate monitoring measures. This is possibly the most underdeveloped element of EIAs in regard to health issues. Most often, the only measures taken are those that relate to toxicological impacts. However, because of the various potential repercussions of some projects, a number of indicators of psychosocial stress or social morbidity could be added to monitoring procedures such as mental pathologies, substance abuse, depression, suicides and so on. In the case of physical health, it should be possible to follow the pattern of accidents related to changing land use configurations and transportation corridors, and certain pathologies indicative of physical or social stress directly or indirectly related to the projects (e.g. STDs).

Ideally, in the case of mental health, evaluators should ideally be psychologists or social workers, and medical experts should be evaluating potential physical health effects (trauma, infectious diseases, STDs, and so on). However, most of the time, if health effects are at all evaluated, this is undertaken by social scientists. With any luck, this person has some medical expertise (e.g. medical anthropologist, sociologist or geographer). In many SIAs, health effects are not identified as such and can be found under a number of headings (nutrition, land use and occupancy, polity, social control, etc.) and can be referred to simply as either social or psychosocial impacts.

Different elements related with a development project can generate psychosocial stress and problems in the community, for instance because:

- the appeal of the new jobs offered can have a skimming effect on community leadership and authority;
- clan or political affiliations might create unequal access to employment;
- absence of local workers from home, increased worker substance abuse or inordinate gambling and spending patterns generate household tensions;
- social or cultural misunderstandings and tensions can arise during interactions between the workforce and neighboring communities.

The above elements can sometimes be found described in SIAs. However, two other potentially important problems that can arise are less seldom mentioned. First, inadequate environmental communications by the promoter can induce undue fears and generate risk-related anxiety in neighboring communities. Second, local perceptions of environmental integrity of the land can be affected by the proposed project, which can foster a feeling of loss of control as regards environmental health issues (cf. Grondin and Bruneau 1994).

In social sciences literature, various psychosocial impacts have been associated with perceived environmental degradation and change, in particular: phobic reactions, adaptation problems, distress, disruption of interpersonal relations and a diminished capacity of individuals or groups to function adequately. These impacts often translate as impressions of loss of control over health, loss of trust in organizations, increased somatization, calling upon various heuristics to explain the etiology and perceived consequences of health effects, and so on.

Various standardized questionnaires (e.g. Social Adjustment Scale, Hopkins Symptom Checklist-90 Item, GHQ-20, CLES, etc.) based on auto-evaluation have been developed to address the quantification of these problems (e.g. Foulks et McLellan 1992, Dunn et al. 1994, Taylor et al. 1991). However, the main difficulties in using methods such as these is that they are time consuming, and the fact that they might be considerably more useful as monitoring measures than as predictive tools for impact assessment.

Other health issues not usually discussed in SIAs

Occupational Health: Discussions in SIAs typically avoid mentioning occupational health. On the one hand, no mentions are usually made on the costs related to additional medical evacuations or regular support to the project's nursing staff by local nursing stations or hospitals, nor on indirect costs of increased pressure on social services if psychosocial problems increase in neighboring communities.

On the other hand, most often than not, potential impacts concerning occupational exposure, hazards and health are not considered in EIAs, essentially because this is understood as being either covered by official occupational health and safety protocols or as management's responsibility. In some cases, this is most unfortunate because many employee integration problems and related costs could be avoided if due diligence were applied before project implementation. For example, some of the potential problems not usually covered by occupational health and safety protocols are:

- accident rates due to the absence of training programs specifically tailored to enhance worker safety in view of unfamiliar work environments and equipment;
- psychosocial stress and adaptation problems due to:

  - long periods of absence from home because of commuting operations, with effects on both the workers (inactivity, estrangement from support networks, loss of family control) and their families;
  - cross-cultural adjustment problems between workers and staff or between co-workers aggravated by training background, cultural misunderstandings, religion, language and communication barriers, etc.;
  - high worker turnover in relation to a lack of incentives, of positive discrimination or of industrial time and space adjustment strategies;

- physical fatigue from:

  - long work periods (in commuting operations, work schedules are often 12 hours a day, seven days a week for the duration of the time on site);

  - lack of adequate leisure and sport facilities;

  - worker circadian rhythm maladjustment (sleep cycle perturbed, tension and stress);

- nutritional problems (diet quantity and/or quality imbalances) as well as lifestyle changes (e.g. increased smoking or substance abuse) in long-distance commuting operations.

Nutrition: The object of describing nutritional behavior (particularly country food consumption) in neighboring communities lies in the need to evaluate potential impacts in terms of the natural resources that contribute to local diet and that can be affected by the proposed project. Very few or no new data are usually generated in this part of the assessment. In sum, most of the work is simply the collection of dietary surveys available or, at the very least, a summary description of hunting, fishing and trapping activities to provide estimates of important foodstuffs. This can also sometimes be complemented by interviews focusing on local food values or preferences. For these reasons, plus the fact that nutrition surveys are rarely undertaken and that funding is typically limited, the work is usually done by social scientists.

Nutritional changes can be due not only to direct impacts on the natural resources but also because of indirect social and economic repercussions such as:

- reduced access to country food because of the loss of providers working for the proposed project;

- land use pattern changes due to indirect environmental disturbances (such as noise, runoffs or increased circulation on the land or waterways);

- changes in local consumption and spending patterns (i.e. increased access to imported goods and foodstuffs).

Social control and deviation: Though data on public safety (such as crime rates) is sometimes provided in the descriptive part of the SIA, it is often not integrated in the analysis or impact evaluation part of the SIA because of conflicting ideologies. For instance, if an evaluator has indications that the proposed project might increase public unrest, the project promoter can counter that this may not happen because jobs will be offered, spending power will be increased, and everybody will be happier. This is thus a subject where ideologies often clash. While it is true that these changes are difficult to predict, if they were taken more seriously monitoring measures could be designed to adequately follow some of the project's effects, and adjust accordingly with mitigation measures when possible.

The possible increase in the incidence of social pathologies and morbidity related to problems such as prostitution, STDs, substance abuse, violence and so on should be taken seriously in some contexts, and for some proposed projects. Increased cultural sensitivity training for workers, or development of adequate leisure and sport facilities for the workforce can sometimes be simple mitigation measures that can help canalize and curb some potential problems. However, in regard to this type of effect, there might be some debate about social responsibility between the stakeholders: in the final analysis, who is accountable for potential social problems, the promoters or the communities?

Ideology: Not often specifically labeled in SIAs, community concerns, norms, values, beliefs, and attitudes are all elements that social scientists typically document in relation to local social structures (identity, family, community, education, bureaucracy and politics, youth and elders, work and leisure, gender relations, power, social change and development), to land use and occupancy patterns, and to the proposed project. These elements can -and should- typically be found disseminated throughout SIAs because they provide valuable insight on project acceptancy, potential social impacts, and fundamental community perspectives.

Ideology is a fundamental determinant of illness, disease, sickness and health (e.g. Eisenberg and Kleinman 1981, Fabrega 1974, Zimmerman 1980). Sensitivity to local concerns, norms, values, beliefs, and attitudes provides a certain measure of the SIAs ability to adequately predict potential effects. However, because of the limits of SIAs (in terms of resources available) very little should be expected of the possible quantification of these impacts.

Social Science Methods - The Strategies of SIA

If and when a SIA is necessary in an EIA, the evaluation methods possible can be grouped under four main strategies: literature reviews, observations, interviews and questionnaires (cf. Bernard 1994, Livesay et al. 1984, Olsen and Merwin 1977, Jaakson 1985, Grawith 1993, Sayer 1992). Each of these research strategies can be combined and can use different techniques and tools. In truth, however, a number of elements determine which methods are used by the evaluators, such as: the originality and expertise of the social scientist, the funding and time available, the latitude given to the consultant by his company and by the promoter, the willingness of the population to participate, and so on.

The following section will provide a brief overview of the usual practice of social impact evaluation in order that readers of SIAs may be able to have some idea of the validity of the data presented to them.

How is the Research Framed?

Research design: In social sciences, as in other sciences, ideal experimentation (i.e. the basic set-up for a two-group randomized pretest-posttest design) must build on four basic principles:

- two groups are needed at least, an intervention group and a control group;

- people must be assigned randomly to one or the other group;
- different variables (e.g. knowledge, attitudes, values, health indicators, economic status, etc.) are measured before an intervention (for example, a development project, a policy or a program) is implemented (pretest);
- the same variables are remeasured and the extent of changes is evaluated after the intervention is implemented (posttest).

In real life situations, social sciences can rarely build true experimentation conditions. Most of the time, the best they can do is natural experimentation, which is when the conditions and the timing of the interventions are not controlled by the social scientist, they are simply evaluated. A fundamental problem with this type of evaluation is that there is most often insufficient baseline data (i.e. no pretesting) to evaluate the impacts of an intervention.

In natural experiments, pre-tests are most often simply not possible (because intervention or change has already occurred), thus one often does not have the choice but to use a one-group posttest design (also called a prescientific design), where through interviews, the social scientist tries to assess the impacts of an intervention. Needless to say, it is very difficult to evaluate if the observations of a given evaluation are the result of a specific intervention or project. Usually, to improve the one-group design, the social scientist evaluates the same variables in two or more groups (one where intervention has occurred and others where there was no intervention). In fact, the more control groups are added, the more one can reliably evaluate the impacts of a given intervention or project.

To undertake SIAs, conditions for ideal research are even more limited. First of all, there are practically never any control groups considered because the mandate of the SIA is to cover only those communities most directly impacted by a proposed project. Next, sampling is absolutely not random (see sampling below). Finally, and most importantly, SIAs do not undertake any posttesting because they only include, per definition, a baseline description of the social environment, a projection of potential impacts and suggestions for mitigation and monitoring measures. In conclusion, SIAs could be called a one-group pretest only design. Consequently, at best impact projections will be based on comparisons of impact outcomes of development projects in other contexts, but numerous differences are likely to influence the value of these inferences (i.e. projects or interventions differ, characteristics of communities impacted differ, evaluation protocols differ, and so on...).

In sum, no experimentation is done in SIAs, and no actual hard science data is generated. One way to overcome this limit of SIAs is to build on one of its strengths, namely: SIAs may include good descriptions of existing conditions before a project is implemented (pretest), in particular a description of the social environment, of land use and occupancy patterns and of community concerns or ideas about potential impacts. Thus, through monitoring activities, pretest-posttest research could be done to evaluate the real effects of development projects.

In the best of cases however, if the conditions of the interventions (i.e. project implementation) are well-known, and if a multigroup pretest (i.e. SIA descriptions)-posttest (i.e. monitoring activities) design could be set-up, this would at best be a quasi-experimental test design because distributions of people in control and intervention groups would not be randomly assigned, and because the validity of comparisons between communities would remain limited given that the effects of potentially different socioeconomic, historical or other factors cannot be controlled fully in the evaluation.

Sampling: The context of SIA rarely if ever provides the social scientist the opportunity to undertake random sampling procedures. In cases where large populations are involved, then systematic random sampling could be used. But again this is rather rare, a project being defined in EIAs as normally impacting only a small part of a large community (e.g. those people living closest to the project, those using resources potentially impacted by the project, those commuting through the EIA area, and so on).

Because sampling is not random in SIAs, most of the time social scientists will resort to locating key informants, who are essentially the people the most knowledgeable or the most directly concerned by what is being measured.

To supplement this key informant approach, other groups not directly affected will sometimes also be met. This is a variant of stratified sampling which is used when an important subgroup is likely to be underrepresented in the sampling approach. For example, if the key informants are those that presently use a given resource that might be potentially affected by a project, then the social scientist might also want to get some representation from previous users (e.g. elders) or future users (e.g. youth). This type of sampling remains disproportionate in that key informants are oversampled compared to the other strata since they may be able to provide essential data to evaluate the project's impacts.

Because survey conditions used in SIAs are rarely based on random sampling, they nearly always have a non-probabilistic approach. Their sampling methods thus often have little external validity. However, if the sampling justification is clearly indicated and supported by adequate baseline data, SIAs can still lead to credible analyses.

The three most often used sampling strategies in SIAs are clustering, haphazard and snowball sampling. Clustering is simply a technique used to identify those natural groupings or associations where key informants are likely to congregate. For example, this might be hunters' and trappers' associations, ecological groups, neighborhoods, etc. Snowball sampling is when key informants are asked to identify other potential informants. In small communities this can be very effective because most people are likely to be in contact with each other. But in large communities, one is likely to oversample specific subgroups of informants with this technique. Finally, haphazard sampling is sometimes the only solution left to the evaluator because of the context of the SIA (e.g. timing for the SIA is not good to meet important informants; reluctance or resistance of local populations to participate in EIAs because of disapproval of the project...). In these cases, the evaluator will have to rely on those who are willing to participate, or have a vested interest in doing so.

Unfortunately, in most SIAs sampling techniques are not catalogued as such and limiting conditions are rarely specified, thus the burden rests on the readers of SIAs to interpret what types of sampling were undertaken to determine some of the limitations of the studies.

How is the Data Collected?

Literature Review: As in any other type of research, the first, essential, and most basic step when initiating an SIA is a search of the literature, both published and unpublished. In some SIAs this is, in fact, the only data gathering phase. Thus, the evaluator should, at the very least, have compiled the socioeconomic and health data available on the communities affected by the project, as well as have read the most important literature on the social and cultural organization of these communities, and should at least have some data on the important historical evolution of the area. Also quite important is gathering the data on land use and occupancy in the EIA area (often available as "grey" literature, or through municipal, provincial or state land planning and resource management agencies).

Ideally, the evaluator should be able to base his projected impacts on a comparison of impacts or SIAs undertaken in similar contexts (i.e. similar project type and size, as well as impacted community characteristics).

Observation: In cases where data are not readily available but necessary (e.g. the number and characteristics of people accessing an area or using a specific public or private utility during a given period), fieldwork might be necessary to observe and generate the information needed. The usual method is that of non-participant observation.

In rare cases, SIAs might mention participant observation, which is when the evaluator establishes an intimate rapport with a given group and shares or helps in its activities. This is very useful to gain insight into insider knowledge of a context and putting into perspective the information useful to evaluate social impacts. This method is typical of ethnographic work which is undertaken to collect in-depth data on a specific culture or sub-culture, to discuss sensitive or intimate topics, to do human ecology work, and so on. However, the time and energy needed to build sufficient trust and to justify the presence of an outside observer nearly always exceeds what is available for a SIA.

Interviews: As mentioned previously (in the section on sampling), when people are actually met in the communities, key informants are often used as the sole source of information. However, using key informants does not guarantee valid data. For one thing, informants might lie about or exaggerate certain information. Also, the informants met by the evaluator are not necessarily the most competent.

Different methods such as via triangulation or verifying cultural consensus (Romney et al. 1986) can greatly help put the data provided by informants into perspective and give an added measure of validity. However, in SIAs there is rarely any information available on such tests having been done. Moreover, because of different types of pressure on the evaluators, it is very rare that informant validity tests are undertaken. Consequently, the analyses often tend to mix together information from informants with different levels of competence in the questions covered by SIAs.

Open-ended interviews with individuals or a group of informants are frequently used in SIAs. There are essentially two types of approaches, either unstructured or semi-structured interviews (the latter are those often used in focus groups). Unstructured interviews are common in ethnographic work, where time is not a problem, but very rare in SIAs because it implies (once the informant has been briefed on the interview objectives) that the interviewer intervenes only when absolutely necessary during the responses.

Semi-structured and structured (see below) interviews are usually the norm in SIAs, in particular because time is limited and the evaluators must maximize the information gathering strategies. In semi-structured interviews, an interview guide is used, which is a list of subjects that must be addressed, and informants are probed with specific queries when they deviate too far off topic. This provides some degree of freedom to let the informant suggest new associations or ideas, and helps the interviewer cover the minimum data needed.

Structured interviews are used when the evaluator needs the different informants to answer questions in a specific order and worded in a specific manner. This is necessary when comparisons between informant responses are needed. Less often used in SIAs since they do not necessarily add to the predictive power of open-ended interviews, this type of interview is nevertheless interesting because it provides information that can be categorized and analyzed quantitatively. Different techniques (such as free listings, sentence framing, triads, taxonomies, ranking and rating) can be associated with structured interviews to elicit underlying meanings or knowledge. However, these techniques are seldom used because the degree of analysis usually required to interpret the data would quite likely drain the resources available for SIA, and the type of measures that could be obtained would most often exceed what is expected of EIAs.

Questionnaires: Finally, where funding and logistics permit, SIAs can use different types of questionnaires (self-administered, interviewer assisted, telephone or mail surveys, etc.) to gather quantitative data, but this is usually limited to some very specific questions. Each type of questionnaire has its advantages and limitations, but the main drawback to using a questionnaire design to collect social data is due to the context of the SIA (i.e. communities will be reluctant to answer sensitive issues in a questionnaire perceived to be issued by a promoter). Thus, the response rate can be quite low and different potential biases can seriously compromise the validity of the data obtained, which is why evaluators usually refrain from using a questionnaire.

How about Validity?

While reading a SIA, one might wonder if the evaluation was well-done or if it meets professional standards and principles. It is difficult to answer these questions because SIAs often do not indicate all the data necessary to undertake a meta-evaluation.

Moreover, the only formal agencies that usually evaluate SIAs are environmental assessment review boards and the authorities in charge of permitting procedures. In most cases, when evaluating SIAs, best practice judgments usually apply. SIA evaluators often have to deal with one or many of the following typical problems of the impact assessment process:

- the elements required to be evaluated are not clearly formulated or are not really measurable;
- stakeholders hold unrealistic expectancies (too high or too low) about the work of SIA evaluators;
- the project definition and parameters change during the course of the evaluation;
- SIA bothers everybody;
- time and resources allotted to SIA are often limited;
- the promoter or the population (or both) are not cooperative;
- very little baseline information is available; and,
- stakeholders try to force their agendas on the evaluators.

The limits of interpretation: The final objective of EIAs is to delimit the probabilities of social and ecological risks related to a project, and to define the measures necessary to minimize them. In the process of evaluating these potential risks, many uncertainties have to be dealt with in EIAs. These uncertainties can be reduced (made measurable or more predictable) in some cases, namely by gathering more data, evaluating more parameters. In other cases, however, some uncertainties are apparently irreducible, either because of their nature (phenomenological limits) such as in non-linear, chaotic systems, or because of our structure of knowledge (epistemological limits) such as when we try to interpret meanings cross-culturally or when we try to synthesize complex, dynamic and multioriented social systems (cf. Faber et al. 1992).

Conclusions

What can health professionals do with SIAs? Given their usual position as external reviewers and sometimes collaborators. Their main input to SIAs lies in knowing how to translate health determinant concerns into research questions for the SIA evaluator. Consequently, their principal role in using SIAs is to translate back the social science output into useful predictions on health issues.

Finally, keeping in mind the basic difference between social impact assessment and social impacts of EIA studies (i.e. "products" versus "processes"), health professionals can help ensure equity in the EIA process by facilitating part of the dialogue between local communities and promoters. This is essential because the relative importance given to the various risks associated with a project, their perception in fact, varies according to the specific interests and agendas of the stakeholders, i.e. the promoters, the consultants, the government authorities, and the populations concerned by the project. Sometimes, the positions held by the various stakeholders of the impact assessment process are simply incommensurable. In a context such as this, it is essential to focus the debates on the primary issues of the environmental impact assessment process, namely the negotiation of risk acceptability and of the definition of realistic probable versus possible impacts.

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

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Part 4 of 9

Human Health Evaluation in Environmental Assessment

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Introduction

In a recent report jointly published by Health Canada and the International Association for Impact Assessment (1), attention was drawn to human health as an essential component of environmental impact assessment. Including investigation of health into Environmental Impact Assessment (EIA) could lead, among other benefits, to the prevention or reduction of adverse health effects and help to identify early warning signs that adverse health effects might be occuring. The report also recognized the absence or relative inadequacy of human health evaluation of most current EA projects.

In this chapter, guidelines for health impact assessment (HIA) of environmental development projects are proposed. Although it is recognized that the concept of health encompasses many facets, including psychological, social, and other factors, the focus will be on physical health. The target of the discussion will be on major environmental development projects with potential health impact on the surrounding population and for which studies of an epidemiologic nature need to be considered. The aim of environmental epidemiology is to determine whether a link exists between health outcomes and environmental factors, defined as "exogenous to and nonessential for the normal functioning of human beings" (Hertz-Picciotto, 1998), and "outside the immediate control of the individual" (Rothman 1993). In this context, it must be borne in mind that the causes of individual diseases are generally multifactorial involving an interplay of genetic, lifestyle, occupational, environmental or other factors, with some having a more dominant role than others. For example, in lung cancer, lifestyle (cigarette smoking) and/or occupational factors (coke oven workers, uranium workers, asbestos workers) may play a major role; genetic and lifestyle factors (diet, smoking, lack of physical exercise) contribute to the development of artheriosclerosis, and genetic, lifestyle and hormonal ones to breast cancer. It is thus difficult to disentangle, in a given disease, the effect of each potential risk factor and determine the contribution of an environmental one. An added difficulty relates to the long latency of many diseases, cancer in particular, which may develop decades after the exposure took place. However, for diseases with acute or subacute manifestations triggered by an environmental factor, such as an asthmatic reaction for instance, a link between an environmental factor and a health outcome may be easier to identify.

Side Bar 1: Hospital Admissions Data

Epidemiologic Study Design

Epidemiologic studies can be either experimental or observational.

Experimental studies:

The question addressed from a HIA point of view is: what are the health effects of a given exposure? The scientifically ideal epidemiologic study design is the randomised controlled experiment where individuals or groups are randomly assigned to different exposure levels and then followed prospectively to assess any difference in outcome. The main advantage which distinguishes experiments from observational studies is that subjects' assignment to exposure is randomised; this minimizes bias by ensuring, a priori, that "extraneous risk factors" are equally distributed and that all exposure groups under study have the same baseline risk of developing the outcome. In the example shown if Figure 1, among 12 exposed subjects, 8 developed the outcome of interest, representing a 66.7% risk or probability of developing the outcome. By contrast, only 3 of 24 (12.5%) unexposed subjects did so. The effect may be measured either as a risk difference of

54.2% (66.7%-12.5%) or as a risk ratio of 5.3 (66.7% ÷ 12.5%). However, only therapeutic and preventive experiments can ethically be conducted in humans. Experimental or intervention studies are unethical when applied to potentially hazardous substances as in environmental epidemiology, hence the reliance on observational studies.

Observational studies

- *Cohort study*

In a cohort study the question addressed is the same as for an experiment; namely, what are the health effects of a given exposure?

A cohort study represents the observational study design that most closely resembles an experiment. Exposed and unexposed populations or groups determined at one point in time are then followed to assess differences in health outcomes between them. Follow-up from exposure to outcome is the key feature shared by both experimental and cohort studies: it gives assurance about the sequence of events, namely the occurrence of exposure prior to the outcome, a basic requirement to infer causality. However, in a cohort study, the investigator controls neither the exposure conditions nor the attribution of exposures to study subjects; thus, contrary to experiments where exposures are randomly assigned after study subjects have been selected, subjects in the cohort are selected after exposure status has been characterized. As a result, risk factors of the health outcome are more likely to be unevenly distributed between the exposed and unexposed groups leading to differences in baseline risk. This comparability problem is a characteristic of all observational studies. In a cohort study, to ensure relative comparability between the exposed and unexposed subjects, the investigator can only control the selection of the unexposed referent (or control) group. Cohort studies may either be prospective when subjects are identified at the present time and followed into the future, or retrospective when subjects are identified in the past and followed up to the present. In prospective studies, the information gathered is tailored to the needs of the study, whereas retrospective studies use available data records that were generally developed for other purposes. Prospective studies although more accurate are costly and often impractical due to their time requirement; retrospective studies are more frequently used as they are faster and cost less.

Two measures of effect are used in cohort studies. The risk ratio or relative risk is the proportion of the exposed cohort developing the health outcome of interest relative to the unexposed referent one. A useful and frequently used measure is the incidence (or mortality) rate ratio which is the incidence rate of the outcome in the exposed group relative to the unexposed one.

- *Case-control study*

In a case-control study the question addressed is the same as from a HIA point of view; namely, what are the contributing environmental causes of a given disease?

Case-control studies, also called case-referent studies, are the most frequently used epidemiologic study design. They examine cause-effect relationships from a perspective opposite to that of cohort studies. They first identify and select "cases", that is subjects with the health outcome of interest, and "controls" or "referents", that is subjects without the health outcome of interest. These groups are then followed backward in time to assess whether their respective past patterns of exposures differed before the cases actually developed the health outcome. Tracking backward from outcome to antecedent is characteristic of case-control studies; it is inferred that differences in exposure patterns between cases and controls are likely causes of the outcome. The case-control design is shown schematically in Figure 2: the same underlying population and association presented in the experiment and cohort studies outlined in Figure 1 are assumed, and all 11 cases which occured in the example from Figure 1 are selected. We then select 11 controls, hopefully a representative subset of the 25 non-cases in the population. Usually, all cases occurring in the population of interest are included in the study, but only a fraction of the potential controls are selected. This makes case-control studies more efficient: one does not have to study all the persons in the populaion who do not develop the disease but only a small sample from them (up to 4 or 5 for each case in a large population). Unfortunately, the case-control sampling scheme hampers computing any direct measure of risk, because the resulting sample of cases and controls is not proportional to the numbers of cases and non-cases in the underlying source population.

Data Sources For Epidemiologic Health Impact Assessment

Population data:

Population figures by sex, age groups, and time periods are essential to estimate disease rates over time in the studied population. From a HIA point of view, data for various age groups, including children and the adult population, and broad time periods, for instance 10 to 15 years, should be considered. Population figures are available by census subdivisions and may be obtained from Statistics Canada which conducts census surveys every five years in Canada. Population figures by enumeration areas, the smallest geographic unit for which such information is available, may also be requested; they may be useful to help determine wether a health hazard affects predominantly a certain area within a town.

Health outcome data:

- *mortality*

A computerized database containing information on causes of death exists in Canada since 1950 (Smith); it includes the name, sex, age , address and cause of death of the decedent; this data may either be obtained directly from each provincial/territorial vital statistics deparments or, for all provinces/territories and Canada as a whole, from Statistics Canada. Mortality databases include information from which rates from any cause of death (cancer, non-cancer diseases, accidents and poisoning) may be reliably estimated; they however, suffer from a number of limitations, notably the lack of information on residence duration.

- *cancer*

A computerized database containing information on cancer incidence exists in Canada since 1969 (Band et al). It includes the name, age, address, cancer site and histology for every newly diagnosed cancer patient; this data may either be obtained from the respective cancer registries for each province/territory or, for all provinces/territories and Canada as a whole, from Statistics Canada. Cancer information from cancer registries is more precise than that obtained from mortality databases as it includes histologic diagnosis of the tumor but data on residence duration is also lacking. Canada is one of the few countries in the world with a national cancer reporting system. The Canadian Cancer Registry is used extensively to identify cancer risks.

- *morbidity*

Information from records collected for administrative purposes such as hospital separation and physician billing forms may be of some value for health outcome measures. However, in general, these records cannot be used to estimate disease rates, but rather frequencies of events, since they are not, as opposed to the mortality and cancer registry databases, based on individual subjects. Thus, for instance, if 100 admissions are recorded for hypertension in a given hospital in a given year, one cannot infer that it was 100 individual cases, as it could be 50 people admitted twice or 10 persons admitted 10 times or any other combinations. In addition, both databases suffer from a number of biases due, in particular to differences in physician's admitting and practice patterns.

- *other*

Specific databases may exist is some, but not all, provinces, that may be of importance for health risk assessment. One exemple is the Nova Scotia Atlee Perinatal Database, which contains data on birth outcomes including congenital malformations.

Health Impact Assessment: Suggested Guidelines

Context

Environmental and occupational epidemiologic studies are generally retrospective in nature investigating health effects of past exposures. Since the objective of HIA is to determine whether new environmental conditions influence future health outcomes, epidemiologic studies in this context must be essentially prospective. However, to document any health effect potentially related to an environmental impact, baseline reference data are required in order to compare the population health status at a future point in time relative to its health status prior to the environmental modification: thus HIA entails both retrospective and prospective epidemiologic studies. Baseline information may also be obtained on the environmental and spatial relationships between the development project and the population and on any known or suspected health effects related to occupational exposures associated with an industrial development. It must also be emphasized as previously pointed out that, in addition to public buy-in, long-term input and involvment of health professionals are essential conditions to the successful implementation of a HIA.

Baseline data

- *Health*

Baseline data on mortality from all causes of death and from cancer incidence may be obtained by means of the databases mentioned above to determine which causes, if any, are statistically significantly increased over the expected rates in nationally or in the province/territory or within the community impacted by the project. In doing so, it is useful to examine whether the disease rates in the town or area of interest significantly exceed those of neighbourhood areas. In addition to providing baseline data, this approach is of help to determine the disease conditions which may prevail in the geographic area of interest.

Box 2

For example, Health Canada investigated the health impact of environmental exposures in Sydney, Nova Scotia, a town that has been the site of heavy industrial pollution for almost 100 years from a steel foundry and coke ovens. A mortality study of all deaths occuring between 1951 and 1994 (Band et al.) has been completed in order to determine whether risks of death from specific diseases were either significantly increased in Sydney only, or showed a significant risk gradient between Sydney and neighbourhood areas, standardized mortality ratios (SMR), a measeure of relative death rates, were compared between Cape Breton County, the census division where Sydney is located, Sydney and Cape Breton County excluding Sydney. Examples of the results are shown in the table.

Table: Standardized mortality ratios (SMR) by geographic areas. Canadian population rates used as reference.

CANCER	SEX	CAPE BRETON COUNTY (CBC)	CBC excluding SYDNEY	SYDNEY
Stomach	Male	1.48*	1.56**	8*
Colon	Male	1.10	0.88	1.69*
Pneumoconiosis	Male	16.8*	16.9**	1.66
Breast	Female	1.09*	1.03	1.25**
Cervix	Female	1.82*	1.83*	1.79*

* : SMR statistically significant

** : SMR statistically significantly different in the geographic area indicated.

It can be observed that for certain diseases such as cerival cancer, although the SMRs are significantly increased in all geographic areas, there is no geographic gradient of risk; for some, like stomach cancer, the SMRs are also significantly increased in all geographic areas, but the risk in Cape Breton County excluding Sydney is significantly greater than in Sydney. For colon cancer in males and breast cancer in females, the SMRs are significantly increased in Sydney only

However, to correctly attribute death or cancer incidence rates to the population under study, it is crucial to ensure that address information actually corresponds to the town of residence of the subjects. There is a tendency for people living at the periphery of a town to use the town's name as their mailing address instead of the name of their locality; this can be reflected on the death certificate or cancer registration form. Such address misclassification may lead to an overestimate of the rates in the population under study. . It is imperative that this problem of residence misclassification be very carefully addressed when ever disease rates are calculated at the sub-census division level.

Side Bar 3: Sydney Tar Ponds

In the study referred to above, all death certificates of Cape Breton County were verified for a one year period. Of the 365 certificates indicating Sydney, only 305 were correctly attributed to Sydney after address and postal code verification. Thus, the number of deaths in Sydney, based on the information contained on the death certificate, was overestimated by close to 20% (60/305) leading to spurious overestimation of disease rates. A number of means were used to estimate the average percentage of address misclassification occuring over the 44 year period of the study, and the SMRs corrected accordingly

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In additon to baseline mortality and cancer incidence data, cross-sectional health survey of a random sample of the population may be contemplated to gather information on the prevalence and frequency of general health conditions and lifestyle factors.

- *Occupation*

For HIA involving an industrial project, a litterature review of health studies should be carried out to verify whether specific diseases have been reported to be significantly associated with the industry under consideration. This information could alert one to potential health hazards to the workers, provide clues to the type of diseases that might possibly be expected in the general population as a result of the new development project, and lead to specific prevention and surveillance measures. Where appropriate, information on mortality from all causes of death and from cancer incidence should also be obtained, using the databases indicated above, to investigate whether workers in specific industries have significantly increased health risks. The characteristics of mortality and cancer incidence databases need to be taken into considerations before interpreting results of occupational and environmental studies investigating cancer risks.

Case Study:

Pulp and paper is a primary industry in BC which produces almost one third of the annual Canadian pulp and paper tonnage. Wood is converted to pulp most commonly by chemical processes. In chemical pulping, lignin is solubilized by chemicals under two conditions: alkaline, also referred to as kraft or sulfate process, and acidic, also called sulphite process, the former being the most common. In a first study by Band et al (1997), investigated the cause of deaths in a cohort of 30,157 workers in 14 pulp and paper mills in BC. Of these, 20373 (68 %) worked in the Kraft process only, 5249 (17%) worked in the sulfite process only, and 4535 (15%) in both processes. Cancer mortality significantly associated with work duration and time from first employment of 15 years or more were: a) total cohort: cancer of the pleura, cancer of the kidney and of the brain; b) workers in kraft mills only: cancer of the kidney; c) workers in sulfite mills only: Hodgkin's disease; d) workers ever employed in both kraft and sulphite mills: cancer of the esophagus. In a second study, the cancer incidence pattern of this cohort was investigated. Cancer incidence significantly associated with work duration and time from first employment were: a) total cohort: stomach; b) workers in kraft mills only: no significant excess; c) workers in sulphite mills only: cancer of the pleura; d) workers ever employed in both kraft and sulphite mills: cancer of the stomach and of the prostate. Although the results of these two studies differ, most of the discrepancies can be explained. Before attempting to do so, it must first be recalled that: 1) mortality data in Canada are available from 1950 onward, but only since 1969 for cancer incidence; 2) information based on pathology report (cancer incidence) are more accurate than information based on death certificate (cancer mortality).

An in-depth look at the two sets of data, cancer mortality and cancer incidence, will serve to identify reasons for the discrepancies observed. For certain cancer sites, discrepancies were more apparent than real: for example, the relative risks for cancer of the pleura and of the brain were of the same order of magnitude in both studies, but were not statistically significant in the cancer incidence study due to smaller numbers as a result of the shorter period of observation. In other situations, mortality data pointed to cancer risks that cancer incidence information could not have revealed: for instance, a sub-analysis by time periods showed that the increased mortality from Hodgkin's disease was confined to the period 1950-1968; thus the cancer incidence results for the period 1969-1992, showing no excess risk concur with the mortality findings for the same time period. Investigations are presently underway looking, in a nested case-control study, if differences in chemical exposures between the two time periods might explain these observations. Finally, for certain cancer sites where pathologic confirmation is essential for precision, different results between cancer mortality and incidence suggest that caution must be exercised in interpreting data based on mortality alone. In the studies by Band et al (1997), the main discrepancies concerned the increased risks of kidney and esophageal cancers which were only observed in the mortality study. For these cancer sites, Band et al (1997) looked at all death certificates of individuals who died between 1969 and 1992 and compared the diagnoses listed on the death certificates with those indicated on the pathology reports obtained from the British Columbia Cancer Registry. There were 46 cases of deaths from kidney cancer for which pathology reports were available in the incidence study; of these, 7 (17%) were not primary renal cell carcinoma; incidence rates for the 39 primary renal tumors did not show an increased risk. For esophageal cancer, of the 31 cases for which pathology reports were available, 9 (30%) were in fact stomach cancers. Thus, the statistically significant results for cancer of the esophagus noted in the mortality study were correctly attributed to stomach cancer based on more precise information.

- *Environmental*

An overview of the environmental conditions of the new project with respect to how they might influence the health status of the surrounding population also needs to be established: for example, the dominant winds, the type of industrial contaminants and their estimated environmental levels, the areas most likely to be affected by airborne, soil or water pollution. Main exposure pathways might also be infered from these investigations.

Prospective data

Once baseline data has been acquired on population health status , occupational health risk and environmental conditions, prospective studies must be contemplated. As discussed above, a cohort study represents the most accurate epidemiologic study design for documenting an association between an exposure and a health outcome. In a prospective cohort study, a population may be stratified into various levels of exposures and then followed over time to determine health outcomes. However, in the context of a HIA, prospective cohort studies suffer from a number of shortcomings:

- they are costly and usually last a long time since the potential health outcomes may be relatively rare and/or occur after a prolonged latent interval;
- as a consequence of the length of time associated with the study, tracing the cohort over time may become very time consuming; and,
- in view of the relatively low levels of environmental exposures cohort studies may fail to document a health risk in an exposed population, especially if the population under study is small.

In the context of a HIA, a cohort study should not be the first option to be considered, rather the following two-phase sequential approach is suggested.

Phase 1: Monitoring

- *Health*: health surveillance of the population should be ensured by repeating every 5 to 10 years the same investigations as those carried out for baseline assessment with particular attention being paid to diseases found to be significantly increased in relation to neighbourhood areas. Periodic monitoring might alert to any unusual deviation from the baseline status which would then require specific investigations. On the other hand, conditions that were significantly increased at baseline, may no longer be significant due to random fluctuation (Deschamps et al.) or to short follow-up or insufficient numbers.

- *Occupation*: establishing the basis that would allow for the long term monitoring of workers and facilitate identification of occupational health hazards in an industrial development project cannot be overemphasized. Firstly, occupational levels of exposures are generally higher than environmental ones; thus a specific disease pattern occuring among workers could serve as "sentinel event" for population surveillance purposes. Secondly, identification of diseases related to occupational exposures are generally derived from retrospective cohort studies where exposure information over time is frequently incomplete or lacking and from which exposure estimates are difficult to establish (Spinelli et al., Astrakianakis et al.). Setting-up at the outset and for each worker the exposure profile associated with each distinct task performed, including exposure to substances listed in the Workplace Hazardous Material Information System (WHIMIS), would enable to develop job-exposure matrices prospectively thus greatly reducing the time and cost of any future evaluation of health outcomes potentially related to occupational exposures.

- *Environmental*: air, soil and water samples, depending on the industrial emission patterns, should be collected in various locations and the concentrations of main pollutants determined. This, in additon to providing reliable information for population health risk assessment, would help to document the relative levels of exposure associated with specific geographic areas.

- *Data integration*: The use of spatial, databases referred to as geographic information systems (GIS), greatly facilitates the integration and analyses of disparate data sources having definable spatial locations and helps to interpret the interrelationships between population health and environmental factors. Mapping mortality, cancer incidence and morbidity patterns over time in relation to environmental exposure, could be established as an HIA procedure on a prospective basis.

Side Bar 4:
HC is are currently using this technique to map the distribution of mortality and cancer incidence *within* Sydney with maps that display the distribution of steel foundry and coke ovens airborne emissions. The town can be characterized into areas of relatively high, moderate and low exposures; map overlays of health outcomes with environmental exposure patterns may help to detect disease clusters associated with high exposure areas

Phase 2: risk factors identification

This phase consists in designing analytic epidemiologic studies to explain the underlying causes of any specific disease condition found to be significantly increased over baseline levels during the monitoring phase of the HIA process. By definition, this phase needs to be considered only if such situation supervenes; furthermore, in view of the long latency of many diseases to which environmental and occupational factors may contribute, these studies are unlikely to be envisioned until several decades have elapse from the time the development project has been implemented.

Exception, however, may occur particularly if toxic substances are teratogens. Since disease risks are multifactorial, the aim of epidemiologic studies at this stage is to determine the contribution of environmental and/or occupational factors, over those of other risk factors such as lifestyle or genetic ones. The epidemiologic methods most adapted will depend on the condition encountered. Among the possibilities to be considered are: a) for health outcomes affecting the general population: case-control studies with detailed residential information; b) for health outcomes in an occupational setting, a cohort study of workers with exposure assessment. In both cases, the data acquired as baseline and during the monitoring phases of the HIA should provide much of the background information required.

Conclusion

In this chapter, guidelines for HIA are suggested, emphasizing prospective data collection for monitoring purposes. Transparence must prevail throughout this process, as well as communication with the public. The population must be informed on a continuing basis of the rationale for the method used, of the type of data collected, of the results and their interpretation. This will ensure a level of understanding and of trust on the part of the population without which a HIA would be compromised.

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

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Roles for the Health Practitioner

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Part 5 of 9

Methodologies for Technological Risk Assessment

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Introduction

Up to the beginning of the industrial age, the simple compliance with rules based on experience was sufficient to ensure the design and construction of relatively safe facilities. However, things changed with the industrial revolution and the implementation of more complex systems, especially in terms of machinery and materials that often required the use of large amounts of energy.

Technological accidents began to occur by the middle of the XIX^th^ century. These accidents generally became more frequent and more serious throughout the XX^th^ century, but it was not until the 60s that it became evident that initiatives had to be taken to prevent such accidents.

There are three main types of technological accidents[1]:

- Accidents related to the manufacture, transportation, distribution, use and disposal of materials (chemical products, infectious substances, radioactive material, etc.);
- Accidents related to equipment and tools (cars, planes, etc.);
- Accidents related to energy-based processes (incineration, cogeneration, etc.).

Technological accidents can include therefore a wide variety of events, ranging from the unintentional release of a single toxic chemical such as chlorine[2] to an incident involving a large nuclear complex[3].

In the 60s and 70s, it was in fact the risk related to nuclear complexes that caused communities throughout the industrialized nations to become more aware of technological risks[4], especially of an extreme nature.

Following this awareness, the nuclear accident that occurred at Three Mile Island in the United States in 1979 and the Chernobyl nuclear disaster that occurred in the Ukraine in 1986 clearly demonstrated that such risks really existed and that they had not been properly assessed. Indeed, the investigations conducted afterwards revealed major shortcomings in the operations of the agencies in charge[5].

These nuclear accidents were followed in the 70s and 80s by several chemical accidents, such as in Seveso in Italy (release of dioxins), in 1976, the Pemex accident in Mexico (gas explosion)[6,7,8], and especially in Bhopal in India (release of methyl isocyanate into the atmosphere), in 1984[9,10,11].

The Bhopal accident lead the federal government to investigate the possibility of such an accident occurring in Canada. This initiative was instrumental in the creation of the Canadian Major Industrial Accidents Coordinating Committee (MIACC)[12]. The purpose of this organization is to reduce the risk of accidents involving hazardous substances through a cooperative approach. MIACC includes members from governments, municipalities, industry, emergency response organizations, labour organizations, public interest groups and universities[13].

Technological accidents often have little or no impact on human life, public health[14], property and the environment[15], but the events described above have shown that such accidents can result in real disasters[16,17]. In addition to the impacts mentioned earlier, they can also result in a crisis[18] among the various players involved or called upon to manage the event[19]. In such cases, the impacts can extend to issues related to mental health in the communities affected[20], maintaining jobs, the corporate image[21], and even to the survival[22] of businesses or to government policy and operations[23].

In Canada as elsewhere in industrialized nations, greater consideration has been given since the early 90s to the risks related to major technological accidents, with respect to both existing facilities and new projects where a major industrial accident can occur. In Quebec, the Department of the Environment and Wildlife (DEW) has issued guidelines on the implementation of environmental impact studies. These initially covered emergency measures planning but now also require in some cases that a technological risk assessment be undertaken[24].

In 1998, there were five (5) DEW directives identifying the type of projects for which a major technological risk assessment is required:

- construction projects for an industrial project;
- pipeline projects;
- waste incinerator projects;
- projects involving dikes, dams, power plants or river diversion projects;
- port or wharf projects.

In the area of risk assessment, the concepts of frequency of occurrence, probability and impact are fundamental because they are used to assess the risk itself. The Canadian Standards Association (CSA) defines risk as a measure of the probability and severity of an adverse effect to health, property or the environment[25].

At least two types of impacts can ordinarily be identified through technological risk assessment: effects on human health and safety and effects on the environment. In the case of the first type, the assessment must include the risk of death, injury or exposure to a hazardous substance within a given group. When an impact assessment is required before an industrial process can be implemented, the goal is to identify any causal relationship likely to affect workers, neighbouring communities and emergency response personnel. In the case of the environment, risk may be more difficult to assess both qualitatively and quantitatively because the range of ecological interactions within an ecosystem is not always well understood.

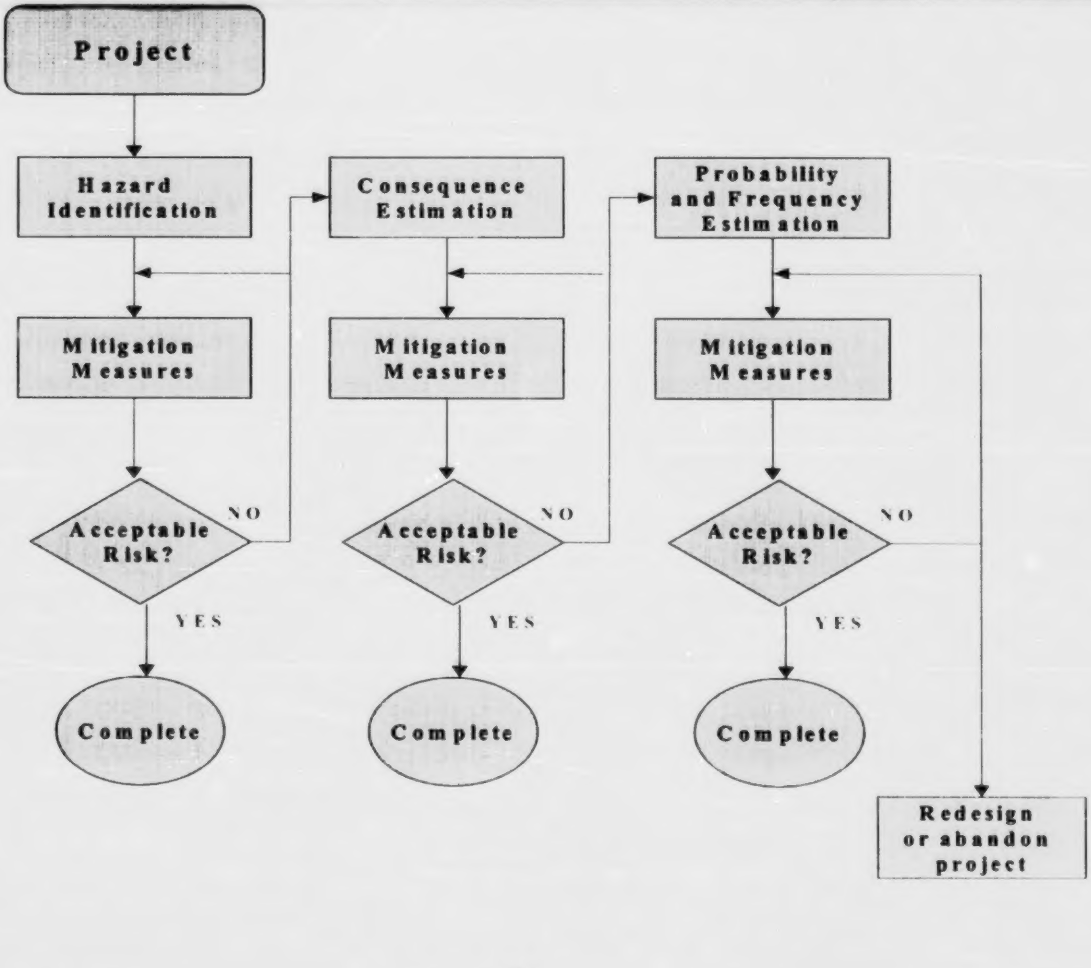
In the case of events affecting human life and public health[26], risk is viewed as the product obtained by multiplying the frequency of occurrence of the event (probability of the event occurring over time) by the probability of negative effects being produced and by the seriousness of the effects[27]. This notion of risk in relation to public health is therefore based on a different approach than the usual formula which includes only frequency of occurrence and the estimated impacts. Indeed, it is essential in the area of public health to consider the probability of occurrence of negative effects, because not all technological accidents result in negative effects on health or human life. Furthermore, the seriousness of the negative effects has to be considered, where appropriate, to ensure a complete risk assessment.

It should be noted that a technological accident can also be identified based on other parameters. According to Dynes, events can be identified according to five parameters: predictability, suddenness, warning time, length of emergency and extent of impact[28]. Burton, Kase and White suggest seven parameters: frequency, magnitude, development speed, duration, surface area, spacing over area and spacing in time[29].

Risk = Frequency of Occurrence of the Event **X** Probability of Occurrence of Negative Effects **X** Seriousness of Effects

Hazard identification, as its name implies, involves drawing up a list of the hazards associated with a project[30]. The OECD defines hazard as "an inherent property of a substance, agent, source of energy or situation having the potential of causing undesirable consequences"[31]. For example, one of the hazards of a mercury vial in a laboratory relates to the toxicity of the mercury vapors to which a person can be exposed if the vial is spilled. In the same way, one of the hazards of a nuclear complex

Figure 1 - Example of a Technological Risk Assessment Methodology


Project
Hazard Identification
Consequence Estimation
Probability and Frequency Estimation
Mitigation Measures
Mitigation Measures
Mitigation Measures
Acceptable Risk?
NO
Acceptable Risk?
NO
Acceptable Risk?
NO
YES
YES
YES
Complete
Complete
Complete
Redesign or abandon project

is the fact that there are large quantities of radioactive substances stored on site. If they are released from a reactor, these substances can produce undesirable effects. Therefore, the term hazard does not include the notion of frequency of occurrence which is used to determine risk.

The aim of hazard identification is to itemize all the components or systems in a technological process and to determine where they might break down. Simple methods can be used to undertake this identification, such as reviewing the relevant literature, but it can also be performed by using a more complex process such as a safety audit.

The use of some of these methodologies can be quite difficult when an environmental assessment is performed prior to the implementation of a technological process. As such, a safety audit implies that there will be a visit to the industrial complex or, at the very least, that a careful review of the company's detailed operating plans will be conducted; it will therefore be easier to perform a safety audit after implementation of the industrial process. The main methodologies are described in the following section of this chapter.

Methodologies for Performing a Technological Risk Assessment

A technological risk assessment as performed by engineering consultant firms[32] in North America usually includes the following seven (7) steps: information gathering, hazard identification[33], consequence assessment, probability and frequency estimation[34], risk quantification, risk assessment, risk management and mitigation measures. Very often, only the first three steps are carried out in a typical environmental assessment as performed by or for an industrial promoter.

When performing an environmental assessment, it can be quite sufficient in certain cases to undertake only data gathering, hazard identification and consequence assessment. The methodologies that can be used for these steps are qualitative or quantitative, but they are accurate enough to identify the causes of a failure, its main consequences, the seriousness of the event and also the preventive measures that should be implemented. Once a pattern is identified, it will be possible to make recommendations to ensure safety and to protect human health and the environment, according to the environmental assessment process.

For the probability and frequency estimation stage, the accepted methodologies imply detailed and extensive knowledge of the technological system being assessed. These methodologies are ordinarily based on a good understanding of the process flow used in the technology. An example of a systems analysis methodology allowing to determine frequencies will be provided in the third part of this section.

Methodologies for Information Gathering and Hazard Identification

Previous experience acquired when implementing various technologies is of course a basic source of information (it is in fact the simplest identification method available). However, when the technology used is new or is not well known, it is suggested to use one or several of the methodologies specifically designed to identify hazards.

These methodologies share several common characteristics[36]:

- they use an inductive approach where the effects on the system being assessed are identified based on a given cause;
- they operate from a fragmentation of the system into subsystems, functions,

components, etc., from which any hazardous element, deviation or failure can be identified in order to determine its consequences;

- they are performed by using data sheets (preestablished tables), where the various columns are filled out by an analyst working alone or by a team (see Figures 2 to 5);
- they help ensure that for each potential hazard identified, the appropriate detection mechanisms are in place;
- they only deal with simple events, i.e., they do not capture (or do so with difficulty) combinations of multiple events likely to lead to a potential risk.

Seven (7) methodologies for identifying hazards are described here, beginning with the most simple. Some of these methodologies have similarities. They differ however in several areas because some have been developed to assess specific hazards (e. g., HAZOP for the chemical industry).

The methodologies described are the following: review of the literature, plant visits, brainstorming - what if, preliminary risk analysis (PRA), Hazard and Operability Studies (HAZOP)[37], Failure Modes, Effects and Criticality Analysis (FMECA), and safety audit.

Review of the Literature: The review of relevant literature can be described as a basic method for identifying hazards. Indeed, any person involved in an environmental assessment process can use it, and it is in fact regularly applied in all cases. This method is especially attractive for several reasons: it can be applied to all products and processes and to all technologies, it can be performed by a single person and it is available to less experienced analysts. Because of these features, a review of the literature can be a very appealing method and also an excellent way to start.

Often articles describing technical incidents or accidents are available. For example, the

Seveso accident of 1976 resulted in the publication of dozens of articles which analyzed both the possible causes of this incident and its effects on health. Furthermore, if there is a little information on how the technology works, it is possible at least to determine which main products it uses. This is done by referring to the documents or data sheets describing these products and their effects in case of fire, explosion or unintentional release.

Some products, such as chlorine, maintain the same basic toxicological properties whatever the emission source. Table 1 provides nine (9) examples of sources of information on chemical products.

Table 1 - Canadian and American Sources of Information on Chemical Products

Organization	Logo	Name of Source of Information	Type of Source of Information
Environment Canada www.etcentre.org	EC - DOE	Enviroguide	Documents published around 1984-1985, approx. 100 pages (currently being updated)
Transport Canada www.tc.gc.ca/canutec	TC - DOT	North American Emergency Response Guidebook, 1996	Paper format also available on Internet (Downloading)
Canadian Centre for Occupational Health and Safety www.ccohs.ca	CCOHS	CHEMINFO www.ccohs.ca/products/databases/cheminfo.html	Available on CD-ROMs, MSDS, and CHEM Source and on CCINFO web.
Commision de la Santé et de la Sécurité du travail (Quebec) www.csst.qc.ca/	CSST	INFOTOX	Accessible by modem and eventually available on Internet

Organization	Logo	Name of Source of Information	Type of Source of Information
US.EPA (Environmental Protection Agency) www.epa.gov/swercepp/tools.html	EPA	CAMEO, ALOHA, etc.	Various tools Visit the site
American Industrial Hygiene Association www.aiha.org/pubs/expopub.html	AIHA	Emergency Response Planning Guidelines (ERPGs)	Paper format
National Institute for Occupational Safety and Health www.cdc.gov/niosh	NIOSH	RTECS www.mdx.com/po-rtecs.htm	Data sheets
		NIOSH Pocket Guide www.cdc.gov/niosh/npg.html	Paper format CD-ROM Disks
National Fire Association www.nfpa.org	NFPA	NFPA-49 Hazardous Chemical Data www.nfpa.org/resources/hazchem_resources.html	Document
		NFPA-325 Fire Hazard, Properties of Flammable Liquids, Gases and Volatile Solids	Document
U.S. Coast Guard www.uscg.mil		CHRIS www.mdx.com/pro-chris.html	Data bank Internet
ATSDR		Hazdat http://atsdr1.atsdr.cdc.gov:8080/hazdat.html	Internet

At the international level, there are *specialized data banks on industrial accidents.* Table 2 provides the address for eight (8) such banks. One of the most useful is a computerized data bank called ARIA (Analysis, Research and Information on Accidents) maintained by the French Department of the Environment. This data bank provides information on accident cases throughout the world. It uses some 2,200 key parameters[38] grouped under four (4) main headings[39].

1. The site
- Location
- Legal and administrative status
- Type of economic activity
- Physical description of the facility
- Human factors in the processes used

2. The event
- Weather conditions
- Typology
- Operating conditions
- Equipment involved
- Failure analysis and determination
- Main products involved
- Personnel involved
- Response and rescue

3. The consequences
- Human implications
- Damage to property
- Loss of use

- Adverse effects on the environment
- Other damages to public property
- Adverse effects on animal life
- Adverse effects on vegetation
- Changes in biological indicators
- Economic implications

4. Aftermath
- Administrative follow-up
- Legal proceedings
- Cleanup and decontamination

TABLE 2 Specialized Data Banks on Industrial Accidents.

(To be inserted)

Review of the literature must not be limited to accessing bibliographical or factual data banks. It must include also consultations with experts working in public or semi-public organizations at the international, federal, provincial, regional or local levels. These experts are usually in a position to provide reports that are otherwise difficult to locate ("grey area literature"), and they can also provide essential personal expertise. Furthermore, in some cases, useful additional information can also be obtained from environmental protection groups. They often have access to data gathered in other countries and acquired through international exchange programs between these groups. In addition, data search through the Internet is becoming increasingly invaluable.

In conclusion, a review of the literature is a method that any person interested in hazard identification can use. Indeed, this technique is available to anyone and not just to experienced analysts. It is important to note also that most impact studies only use this method to identify hazards.

Plant Visits: A plant visit is a method that can be used in many instances, but it immediately becomes more difficult than reviewing the literature because it requires the presence elsewhere in the world of a plant or of a technological process similar to the one being assessed. For such a plant visit to be useful, the team must include experts or people experienced in the area being investigated. Otherwise, the personnel making the visit may be allowed to see only what the plant officers may decide. Furthermore, they will not be able to ask exact questions on the various operations involved in a process.

Brainstorming – What if: This method can be useful to complement a review of the literature or a plant visit because definite issues can be raised such as the presence of certain potential hazards. This method can be applied in any type of process and can be conducted by less experienced analysts. It begins with the general question "What happens if ... ?" and, based on the answers, the possible consequences of a disruption can be determined, recommendations can be made, and an accountable individual can be identified for each situation. The information must be provided in written format, as shown in Figure 2, and it can be compiled as an annex to an environmental assessment report. It is used to describe the type of hazards and also to develop the recommendations included in the assessment report. It should be pointed out that this method requires the input of a multi-disciplinary team and that the experience of this team greatly influences the results. In fact, this is a rather informal method, and because of this, the focus can easily shift to a particular area or hazard at the expense of another that the team's experience does not allow it to address.

Figure 2 - Technological Risk Assessment Based on the Brainstorming-What if Methodology - Example: Incinerator

"What happens if ...?"	Consequences	Recommendations	Officer in Charge	Date Action Taken
1. Pressure increases in incinerator	Overpressure	-Fit incinerator with emergency chimney -Check regularly condition of emergency chimney and of its control system	Plan Engineer	

"What happens if ...?"	**Consequences**	**Recommendations**	**Officer in Charge**	**Date Action Taken**
2. Emergency chimney does not work properly	**- Smoke can leak through gaps in oven - Carbon monoxide (CO) levels can increase - Employees can be exposed to CO**	**- Install barometer in oven and link it to a primary fan - Install smoke and carbon monoxide detectors linked to an evacuation alarm**	**Maintenance Superintendent**	

Preliminary Risk Analysis (PRA) Using Checklists: This type of analysis is performed using a table such as the one shown in Figure 3. Its aim is to identify the various hazardous components of the process or system being assessed and to determine the potential for each of these to degenerate into a more or less serious accident. The analyst performing the PRA relies on checklists showing the hazardous components and situations. These lists are customized according to the area or the technology being assessed. It should be noted that the purpose of the columns with the headings "Seriousness" and "Consequences" (Figure 3) is to set priorities, whereas the columns with the headings "Preventive Measures" and "Implementation of Measures" are used to determine what steps must be taken to identify, control or eliminate the hazard.

Figure 3 - Technological Risk Assessment Based on the PRA Methodology - (Preliminary Risk Analysis)

Subsystem or Function	
Phase	
Hazardous Component	
Event Leading to Hazardous Situation	
Hazardous Situation	

Subsystem or Function	
Event Leading to Potential Accident	
Potential Accident	
Consequences	
Seriousness	
Preventive Measures	
Implementation of Measures	

This method is not designed to provide extensive details. Its purpose rather is to quickly identify the more important problems most likely to occur. It can be used when a project is first submitted, but it is also designed to be updated during development of the project and also during the operational phase of the system being assessed. PRA can therefore be a method that goes beyond the environmental assessment prior to the implementation phase of a project. It can be used to monitor risk after implementation of the system and during its use or operation.

The HAZOP Method: The method called “Hazard and Operability Studies[40] is designed mostly to help identify hazards in the chemical industry. This is a method that has gained wide acceptance in this area because it allows to determine the influence of deviations identified in processes as compared to what these processes should normally do. This method is applied using tables with columns, an example of which is given at Figure 4. In some respects, this is a more formal approach than the “Brainstorming-what if?” method.

Figure 4 - Technological Risk Assessment Based on the HAZOP Methodology (Hazard and Operability Studies) - Example: Incinerator - Subsystem: Air Supply

GW (Group Word)	Hazardous Deviation	Possible Causes	Consequences	Mitigation Measures	Remarks	By:
None	No flow	Power outage Primary and secondary fans not operating Valve blocked close Plugged air filter	Incinerator stoppage Oven explosion Damages to filtration systems	Automatic stoppage in case of power outage Install backup compressor with startup if first compressor stops Weekly maintenance of air filter		

To help stimulate the investigative process, group words are used to represent the extent of deviations compared to nominal values. These include such words as greater, lesser, nil, etc. These key words are used to qualify various types of parameters such as pressure, temperature, flow, etc. In each case, the analyst seeks to identify causes, consequences, detection methods and corrective actions (mitigation measures).

The HAZOP method is used mostly by companies wishing to develop an emergency plan to deal with technological accidents. It should be noted however that data gathered during a prior analysis could be used for the environmental assessment of a similar technological process being implemented elsewhere. The HAZOP method can therefore be used again in the environmental assessment of a project. It can be applied if there is a solid multi-disciplinary team of experts working under the direction of an experienced leader who can rely on the assistance of a technical secretary and who has a very detailed knowledge of the technological application's process flow. The

HAZOP approach is interdisciplinary, flexible, and systematic. With this method, a complete and well documented report can be prepared. The HAZOP method can be computerized and tools (such as HAZOP-PC, HAZOP Plus for Windows) are available on the market.

The FMECA Method: The FMECA method ("Failure Modes, Effects and Criticality Analysis")[41] was developed in the 60s for the aeronautical industry. It later became very popular in the space sector, the chemical industry the automobile industry, and in all technology-based sectors. This method is appealing because it is easy to use and does not require extensive theoretical knowledge. It is therefore available to analysts with little experience and it can be performed by a person working alone or in a team.

The FMECA method focuses on the analysis of the components and equipment linked to a specific technology. As with other approaches that have been described within the chapter, this method uses a specific data sheet like the one reproduced in Figure 5. In general, each technological or industrial sector has its own data sheet from which are derived technical guidebooks, standards or criteria. This method is applied by considering on an individual basis each of the components of the system being assessed and by analyzing each of the areas where this component can fail.

Figure 5 - Technological Risk Assessment Based on the FMECA Methodology (Failure Modes, Effects and Criticality Analysis) - Example: Incinerator - Component: Valve

Component	Failure	Consequences	Mitigation Measures	Additional Mitigation Measures
Valve 1 (Temperature control through propane injection)	Valve blocked open	Increase in oven temperature Refractory breakage Overpressure in oven Danger of explosion	Shut valve 2 High temperature alarm	Install high pressure alarm Inform (handbook) and train employees
	Valve blocked close	Decrease in oven temperature	Preventive maintenance	
	External leak	Fire risk Explosion risk Difficulty in controlling oven temperature Economic loss	Monitor pressure in propane tank Monitor propane levels	Pipe installed on the outside
	Internal leak	High temperature in oven Explosion risk when oven is shut down		Install handbook valve at oven mouth Inform (handbook) and train employees

This method can be refined by adding two other columns, entitled "Probability" and "Seriousness", which can be used together to determine the "criticality" of the failure being investigated. These columns are usually filled with semi-quantitative data, including terms such as "very improbable", "improbable", "significant", "catastrophic", etc.

A study carried out under the FMECA method can be very useful because, before investigating into why a system has failed, it is necessary to know how this system works. In some cases, because of his systematic approach, the analyst has a better understanding of how the system works than the owner himself or herself.

As for the use of the FMECA method in an environmental assessment, the observations made earlier concerning the HAZOP method also apply here. In fact, the FMECA method can be used by anyone with comprehensive knowledge of how a technological process works. This is not always the case for analysts assigned to an environmental assessment. In this type of assessment, it is extremely useful to be able to refer to the results of a FMECA that has already been performed.

Safety Audit: A safety audit, or "systems safety analysis"[42, 43], is a combination of two methodologies: making plant visits and developing checklists. The latter is a formal approach that can be applied to any process and that analysts with little experience can perform. A typical checklist includes several headings whereby a hazard can be identified based on specific areas of concern (Figure 6).

Figure 6 - Technological Risk Assessment Based on a Safety Audit (Checklist) - Example: Danger from hazardous material (chlorine) - Chlorine stock control in a pulp and paper mill

Checklist
Inventory of hazardous materials
- corrosive
- explosive
- flammable
- leachable
- radioactive

Stock levels for each type of hazardous material
- Number of storage tanks
- capacity

Safety measures developed for each storage tank
- high-level alarm
- double liner
- restraining dike
- etc.

Hazardous Material Inventory

Plant: Les papiers du Nord Inc.
Fixed risk sites - Companies

Hazardous Materials

Name	Location on site
CHLORINE	Depart. Vapor (Yard)
GASOLINE	Depart. Yard
GASOLINE	Depart. Yard

Number of containers for this product: 1 Total quantity at this location: 1

Total number of containers for this address: 1

N.I.P.: UN1017

Chemical Abstract Number **Transportation Class**
Class: 2.3

Service **(CAS) 7782-50-5**

State: Liquid
Concentration as percentage by mass: 100% **Comments** **Storage Conditions**

A safety audit can be performed by a single person, but he or she must be accompanied by someone knowledgeable in each of the areas being assessed (fire protection, storage of hazardous materials, etc.). It should be emphasized however that this type of audit focuses on a specific process and cannot be applied as easily to an overall project. Like environmental compliance audits (ISO 14 010 series), the purpose of safety audits is mostly to assess a technological system in operation. However, audit reports on existing processes can be used as support documents for an environmental assessment aimed at a project based on a similar process.

Consequence Estimation

Unlike hazard identification, which is qualitative, a consequence estimation is performed by using quantitative methods providing information on the significance of the anticipated effects[44]. These methods have been described in technical handbooks dealing with problems such as leakages, blow-by, BLEVEs, etc. and published by organizations such as the World Bank[45] and the Institution of Chemical Engineers (IChemE)[46].

When a consequence estimation is linked to an accident scenario, it is possible to determine in which areas the health and safety of neighbouring communities and the integrity of the environment (natural and human) can be affected, and also to take into consideration sensitive issues that have been previously identified. Such information is especially useful for emergency planning[47].

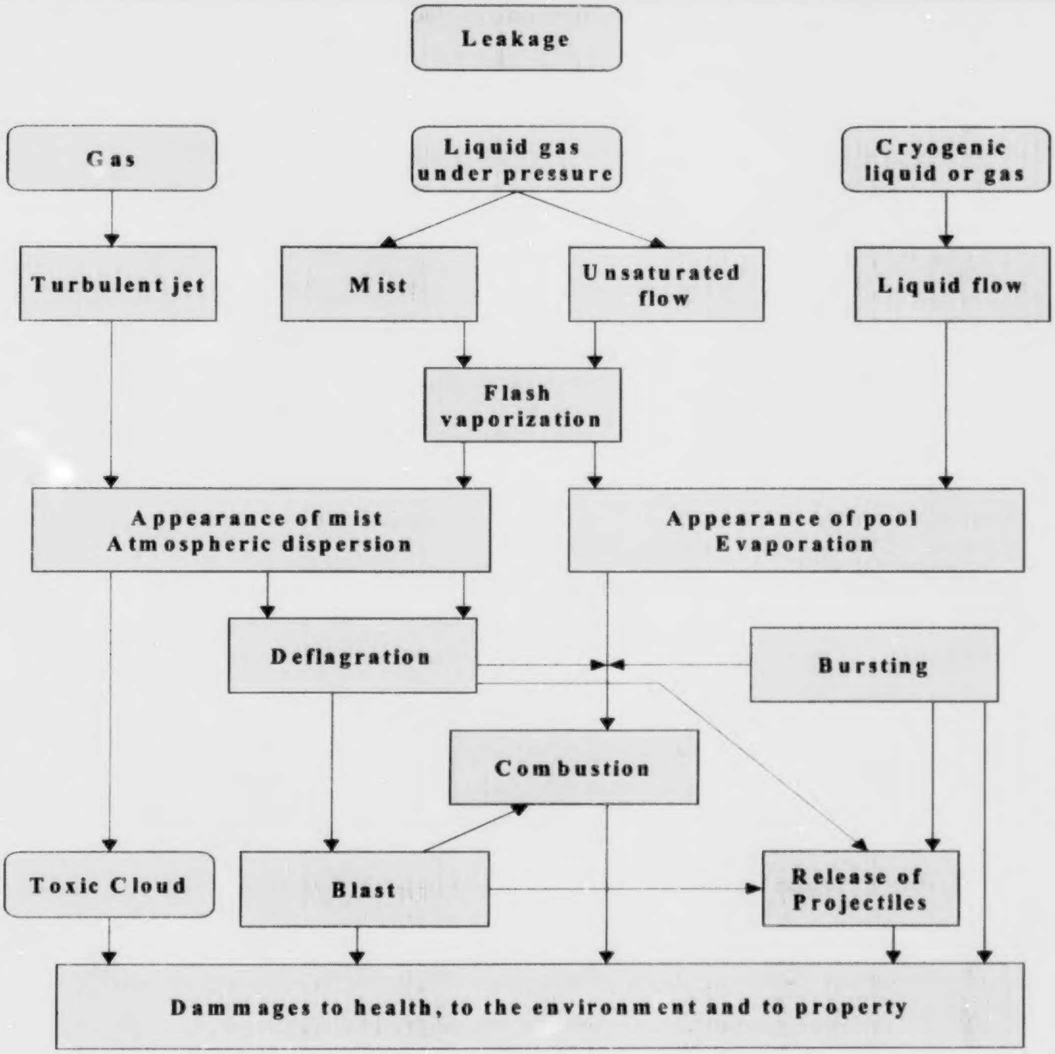
The quantitative nature of a consequence estimation is the result of two types of models used in this type of assessment. Firstly, a set of models called physical or "effect models" is required to assess the purely physical (and/or chemical) consequences of a risk and the damages to property that can result. A second set of models, called impact or "vulnerability models", is then used to determine the exposure of humans to the effects[48].

The physical models are used to quantify the dispersion rate of a gas or a liquid that is leaking from a pipe or a storage tank, for example, mostly with the Bernouilli equation. These models are also used to predict such events as the formation of aerosols and the evaporation of volatile substances. In this way, it is possible to determine the levels of hazardous substances in a poisonous mist. Physical models are also used to determine heat flow in a fire[49].

Figure 7 shows the series of events covered in the physical models to determine exposure in the case of accidents involving flammable or toxic hazardous materiels. It identifies various phases such as breakage, dispersion and ignition, which are usually dealt with at the hazard identification stage. If total destruction has not occurred, the first thing to do is to determine how the leak occurred and how big it is. Various models are then used to determine the flow rate at the leak. This is followed by an assessment of the extent of the dispersion occurring as a cloud or a spill, which can undergo partial evaporation. Finally, if a flammable product is involved, the results of ignition must be modeled. This is done by using models for combustion, explosion or projectile emission[45].

When impact models are used to determine effects on health, these are mostly based on vulnerability models and demographic models (density and characteristics of the affected population). With these models, it is possible to determine for a given event (fire, explosion, release of a hazardous substance) the expected probabilities of immediate or delayed effects in the community[45].

Figure 7- Consequence Estimation Using a Physical Model (Adapted from Degrange, 1993)


Leakage
Gas
Liquid gas under pressure
Cryogenic liquid or gas
Turbulent jet
Mist
Unsaturated flow
Liquid flow
Flash vaporization
Appearance of mist
Atmospheric dispersion
Appearance of pool
Evaporation
Deflagration
Bursting
Combustion
Toxic Cloud
Blast
Release of Projectiles
Dammages to health, to the environment and to property

Probability and Frequency Estimation

The methodologies used to estimate probabilities and frequency of occurrence can be based on an inductive or deductive approach. They can also be qualitative (identification) or quantitative (the estimation as such). With the inductive method, the effects are investigated beginning with the identified failures, whereas with the deductive method, the procedure is the opposite, i.e., the possible causes are investigated beginning with the effects.

In principle, the inductive approach should allow to gather all the required information (including unnecessary or irrelevant data), but it is relatively cumbersome and is therefore difficult to use when combinations of events are being investigated. As for the deductive approach, it is generally well focused and it generates only useful information. However, if the analyst overlooked an item at the beginning, he cannot make up for it elsewhere. The fault tree and the event tree are the best known and most widely used methods to determine frequency of occurrence. They are described briefly in the following paragraphs.

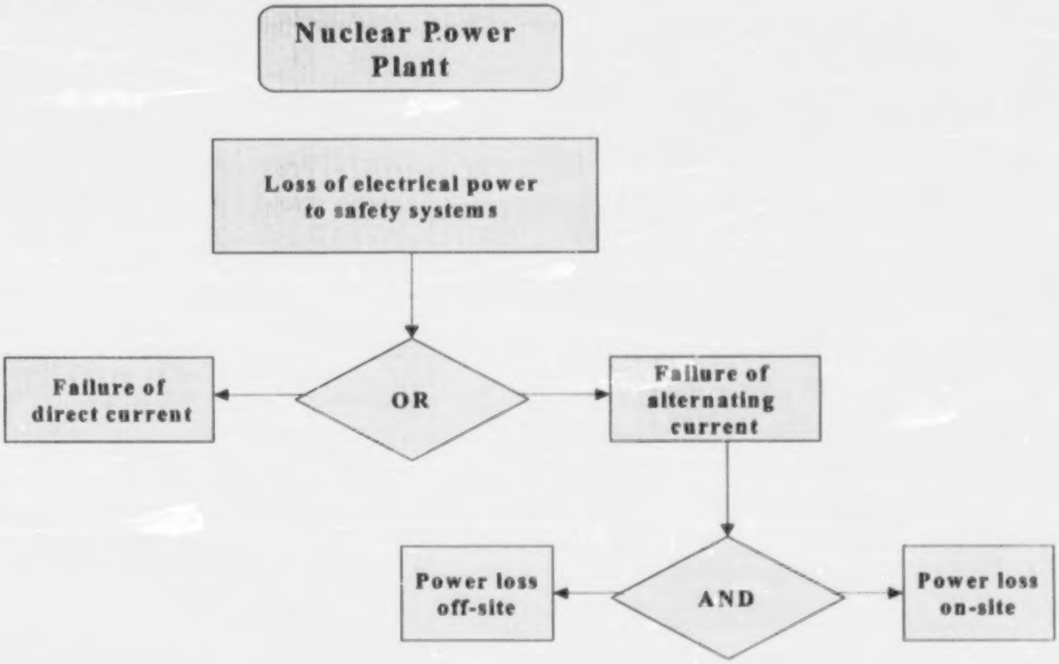
Fault Tree Analysis: Fault tree analysis[50], developed in the United States in the early 60s, is one of the most important technological risk assessment tools. This is a deductive and tree-structured method in which both qualitative and quantitative data can be used. It is used to calculate the probability of failure of a system where there is no historic data available. It is therefore used to assess technological processes where failures are rare and where new systems are being implemented. As such, it can be used for environmental pre-assessments. However, fault tree analysis requires a good knowledge of the system being assessed. To achieve this, the analyst can rely on a hazard identification method such as FMECA, which can provide him or her with the required information on how the system works.

Fault tree analysis involves two major stages: construction and assessment.

Construction is based on the division of the undesirable event (failure) into intermediate events that reveal its immediate causes. These are then divided further into other causes and this continues until any further division becomes impossible or is deemed unnecessary. The division of an event into cause-events is done through the logical operators of AND and OR, (called "doors"). In some cases, the tree can show many ramifications, as illustrated in Figure 7.

To help explain the typical reasoning governing the use of this method, Figure 8 shows a simplified fault tree illustrating a loss of electrical power to a nuclear power plant's safety systems. These systems require an alternating current (AC) to work properly, but the control switches for these systems are activated by direct current (DC). Failure of these safety systems can therefore be caused by a loss of alternating or direct current; the logical operator that must be used is OR. In Figure 8, there is no further division of the intermediate events resulting from the loss of direct current. Division was done only in the case of the alternating current. Here, the logical operator used was AND, because the safety systems work either on power provided by an off-site producer of electricity or, if there is a power outage, they continue working through on-site diesel generators that take over. Therefore, if there is a complete loss of power, it is because these two sources of electricity have failed at the same time, and that is why the logical operator AND is used.

Figure 8 - Frequency Estimation Using Fault Tree Analysis - Example: Nuclear power plant - power loss

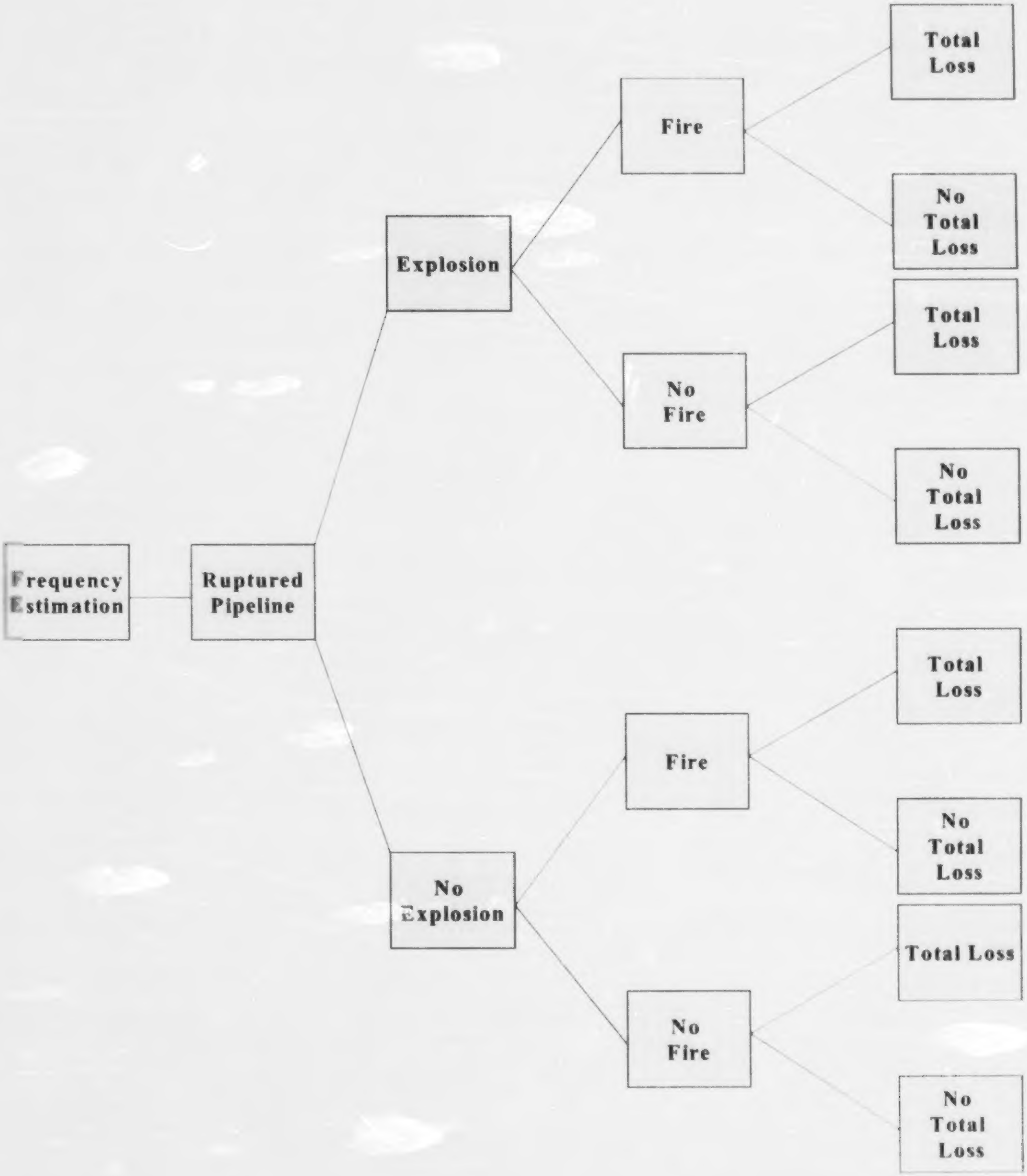

Nuclear Power Plant
Loss of electrical power to safety systems
OR
Failure of direct current
Failure of alternating current
AND
Power loss off-site
Power loss on-site

Division can continue in this way up to the point where the most basic elements, called primary failures, are reached. These can involve switches, solenoids, microprocessors, etc. Once the basic elements have been identified, the second stage, called estimation, can begin. The final estimation as to the probability of occurrence of an undesirable event must take into account the whole range of failure probabilities and/or failure rates linked to intermediate events, each of which has its own failure rate. The overall rate is used to estimate the risk associated with each potential accident.

Event Tree Analysis: Event tree analysis[51] is similar in many respects to fault tree analysis. However, the logic used is different because the process is inductive instead of deductive. In an event tree, the analysis is therefore based on identification of the effects that a failure can produce instead of on failure identification through the effects produced. The process is therefore the opposite of the fault tree. In the simplified example given in Figure 8, the failure could be a breakdown of the power generators (on-site current), and the analyst would attempt to determine its effects (upstream). It should be noted that an event tree does not include decision points requiring the logical operator's OR and AND. An event tree is made up of potential events resulting from a leading event (initiator). Probabilities are determined for each event (outcome).

Figure 9 shows what an event tree usually looks like. The example given is a failure in the form of a break in a propane pipe. Beginning with this event, which has a known frequency of occurrence, the object is to identify the effects or the sequence of events, each of which has its own probability. The probabilities associated with each event (P_1, P_2, $1-P_2$, etc.) are aggregated so as to produce an overall rate for each ramification (per year in Figure 9). In this case, beginning with the failure identified, namely a break in the pipe, the first thing to do is to determine whether there will be an explosion. If no explosion is anticipated, the upper branch is chosen (probability P_2). If an explosion is anticipated, the lower branch is chosen (probability $1-P_2$). In this case, it must then be determined if there is a risk of fire. If there is no risk, the upper branch is chosen (probability P_3). If there is a risk of fire, the lower branch is chosen ($1-P_3$). The same question as to the possibility of fire must be asked even if there is no explosion. When there is neither explosion nor fire, probability P_4 prevails. When there is no explosion but there is a fire, the probability is $1-P_4$. The same exercise is repeated with the probabilities linked to a complete loss.

Figure 9 - Frequency Estimation Using Event Tree Analysis - Example: Break in a propane pipe


Frequency Estimation
Ruptured Pipeline
Explosion
Fire
Total Loss
No Total Loss
No Fire
Total Loss
No Total Loss
No Explosion
Fire
Total Loss
No Total Loss
No Fire
Total Loss
No Total Loss

Frequency of events (Year^{-1})	**Consequence of events (in thousands of $)**	**Economic Risk (in thousands of $/year)**
2 X 10^{-2}	**5**	**100**
3 X 10^{-3}	**50**	**150**
2 X 10^{-2}	**10**	**200**
8 X 10^{-3}	**200**	**1600**
2 X 20^{-3}	**10**	**20**
3 X 10^{-3}	**200**	**600**
0	**0**	**0**
5 X 10^{-2}	**1000**	**50 000**
Total: 1.1 X 10^{-2}		**52 670**

As mentioned above, the last operation is to aggregate the probabilities (failure rates) in each of the tree's branches. Figure 9 shows similar probabilities for all of the situations, but the consequences are considerably different, considering the type of hazards (fire, explosion, complete loss). Thus, a break followed by a fire, an explosion and a complete loss has an economic impact estimated at $1 million, whereas a break where there is neither explosion, fire nor complete loss will lead to a loss (impact) of $5,000. Impacts on health, safety or the environment could of course be featured instead of economic impacts.

Fault and event trees are interesting and useful, but they have certain limitations. Indeed, it is difficult to take into account the human element and especially irrational decisions resulting from a stressful situation or, at the other extreme, from an imaginative solution that could not be included in the initial plan. Furthermore, there is a tendency to simplify the set of events when these trees are prepared; there can be hundreds of minor events or unforeseeable minor failures that the analysts do not consider. Analysts usually adopt a conservative approach (also called worst-case) which excludes imaginative human solutions. For these reasons, it not always evident that a fault or event tree will provide useful or exact information. It should be recognized that these trees are useful to identify potential failures and to take appropriate action before they occur, instead of using them as a prediction tool to determine the rates and frequencies of occurrence linked to a hazard.

Conclusion

Technological accidents such as fires, explosions or the release of hazardous chemical substances can lead in certain situations to serious impacts on the health and safety of workers and of the community in general. It is therefore crucial to take action to prevent such events from occurring in the first place or to reduce their effects.

An important tool for doing this is technological risk assessment. The notion of technological risk is based on the two concepts of hazard and probability. In the case of new projects, some hazards can be avoided at the design stage and those remaining can be dealt with by risk management through various approaches such as safety mechanisms.

The environmental assessment process is a good opportunity to identify hazards and, if necessary, to estimate the consequences and the probabilities and rates of occurrence of undesirable events, to assess the risk, and to propose mitigation measures.

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Terms used in French:
Hazard Identification = Analyse des dangers
Consequence Assessment = Analyse des conséquences
Frequency Assessment = Analyse des probabilités
Risk Quantification = Quantification des risques
Risk Assessment = Évaluation des risques
Risk Management – mitigation measures = Gestion des risques - mesures d'atténuation.

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[51] Event Tree Analysis: one of several method of hazard analysis involving inductive determination of pathways of disturbances having lead to a hazardous situation.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

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Part 6 of 9

Public Health Integration in EIA

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Health in Environmental Assessments

The practice of environmental assessments originated with the US National Environmental Policy Act of 1969 (NEPA). It states as one of its purposes the promotion of efforts "which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man" (NEPA 1969, Sec 2). However, in the practice of environmental assessments, human health considerations were either ignored or given only superficial attention during the 1970s (Go 1988). Although human health considerations have become a specific part of most legislative frameworks on environmental assessments all over the world (Sutcliffe 1995), and though the normative literature on impact assessment considers social and health aspects an integral part of EA, they are frequently left out in real life projects (Ortolano and Shepherd 1995).

In 1986, the World Health Organization held a meeting on the health and safety component of environmental impact assessment. The report of this meeting was one of the first to address specifically the issue of human health in EA. The expert group proposed to use the risk assessment and management process in order to study the future health effects of projects:

> *Chemical risk management is designed to be applied to chemicals without reference to a specific project context, often directed to the setting of regulatory or advisory exposure limits or other controls. The health and safety component of EA is concerned with, among other things, the health effects of chemicals within project or policy appraisal as part of the permitting procedure for that development. Chemical risk management (WHO model) and the assessment of environmental health effects are closely related, but they are different procedures for different*

> *purposes. (WHO 1987, p 2).*

The choice of the risk assessment and management process at that time was not aimed to limit the scope of health impacts to its toxicological aspects. The authors made a pragmatic choice based on the availability of risk assessment as a specific methodology for health. They made the explicit statement that social determinants of health should be included in environmental assessments :

> *The health component of EA should include not only disease-related effects but also all impacts which might change the well-being of neighbouring populations whether it be for better or worse. These might include psychological effects of proximity of certain types of development and improvement in health as a result of increased employment and wealth in a community.* (WHO 1987, p 9)

These statements from 1987 still do apply for today's methodology of health assessments as a specific part of environmental assessments. As Ortolano and Shepherd (1995) have pointed out health assessment is frequently absent even for projects with significant human health impacts. Considerable efforts have been undertaken on an international scale to propose and promote the risk assessment based health assessment process (Turnbull 1992). Go (1988) pointed out some methodological difficulties in applying the risk assessment process to health determinants outside the toxicological aspects :

> *Secondary health and socio-economic effects are ubiquitous in all projects of significance that affect population growth and movements.*
>
> *These types of impact are generally subject to exogenous events that are probabilistic or undeterminable.*
>
> *[..]because of the stochastic nature of physical and biological processes and the fact that the most important health consequences are frequently dependent on undeterminable or probabilistic factors and exogenous events", the quantification of human health is extremely complex.*

According to Go the complexity of the relationships between health risks from toxicological and microbiological sources and health protective factors of economic and social development makes it impossible to construct coherent quantitative models in order to predict the overall impact of a project on the health of a given population. None of the recent publications dealing with public health in environmental assessment (Harvey 1990; Turnbull 1992; Arquiaga, Canter et al. 1994; Sutcliffe 1995) integrate social determinants of health, Comité de santé environnementale du Québec (1993) being the only exception.

A brief historic analysis may help to understand the current limitations regarding public health interventions in the environmental assessment process. Environmental health impact assessments have evolved inside the health protection tradition in the field of environmental health. Environmental health is concerned with controlling health risks associated with the physical environment (HEADLAMP 1995). In the last decade, health promotion has emerged as the new public health strategy expanding the individual lifestyle approach of health education to include collective elements like the physical and social environment and public policies. The framework of health promotion has become so prominent and dynamic that the term New Public Health has been coined to describe this renewal process in public health thinking, intervening and researching (Ashton and Seymour 1988; Dean 1994). In Canada this conceptual renewal process has resulted in the adoption of a health determinant framework for reorienting the health system (Federal, provincial and territorial advisory committee on population health 1994).

Social determinants of health have emerged as the most powerful modifier for population health. The influence of poverty on the health status of a population has been acknowledged for a long time. There is a strong historic correlation between economic growth and mortality rates. Economic growth is inversely related to overall mortality rates with a time lag of up to 14 years. Economic recession, as measured by the unemployment rate and by bankruptcy rate, is positively related to mortality over a 10 year period, with an initial peak of mortality 2 to 3 years after the recession's peak (Brenner 1995). Franks, Adamson et al. (1991) have established a dose-response relationship of 5.4 per 100,00 increase in male stroke death for every 1% rise in male unemployment. Health impacts of unemployment can be shown not only for the unemployed person himself, but for the whole family unit (Canadian Public Health Association 1996). Brenner (1983) showed correlations between infant, fetal and maternal mortality rates and adverse economic trends.

Studies on the contribution of unemployment and poverty to health status select populations pushed to the margins of society to demonstrate the direct and determinant influence of social determinants of health. Social determinants of health are ubiquitous in society. A prospective study which followed 10 000 British civil servants for nearly 20 years established an age-standardized mortality 3.5 times higher in the clerical and handbook grades than in the higher administrative grades (Marmot and Theorell 1988). For all levels of society social integration and mortality are strongly correlated. A relative risk ratio of mortality between 2 and 4 (lowest level of social integration versus the highest level) has been established in different studies (House 1988).

There has been much debate about the exact meaning of strong, positive associations in epidemiological studies between social variables and health outcomes. Unemployment has been one the variables which has received considerable attention from social epidemiologists. A review of available evidence concludes that unemployment fulfills most of Hill's criteria of causal relationship. Although the exact mechanisms are still hypothetical, the available evidence has lead many authors to suggest mechanism of causation (Canadian Public Health Association 1996).

The effects of the external social system are mediated through endocrine and immune pathways. A prolonged physiological stress has been shown to have numerous deleterious biological effects. Members of the higher social and economic class present short term elevation of adrenaline and blood pressure, while members of the lower classes experience a chronic form of stress, leading to higher blood pressure, circulating fibrinogen blood levels and impairment of the immune system.

> **Looking at heart disease among male workers, different studies show that people in jobs that impose unpredictable and uncontrollable demands, yet that leave very little room for individual discretion in responding, and that in addition underutilize the individual's skills and abilities - no opportunity for personal growth tend to have higher rates of heart disease, and death.**
>
> ***(Evans, Barer et al. 1994, p 22)***

The emerging picture of the complex interrelations between social organization, self-esteem and biological systems does not yet permit to build models predicting the effects on population health of modifying certain social parameters. Focusing only on poverty as the principal determinant of population health status is incoherent with today's knowledge of the pervasive influence of social factors in the health of all subgroups in the population and of the complexity of causal relations. For example, advocating the creation of wealth through economic growth and job creation may not be an efficient strategy, in spite of social determinants being the most powerful modifier for population health.

> **[W]ithin the strong cross-national correlation between health and wealth, certain societies achieve aggregate health status measures that are much higher than their income levels would « predict », while others are much lower. [...] the health of a population depends upon the equality of income distribution, rather than the average income, so that rising average incomes can be associated with declining health, if the resulting wealth becomes concentrated in fewer pockets.**
>
> ***(Evans, Barer et al. 1994, p 23)***

In the case of unemployment the fall of social support through unemployment may be central in the causal pathway between unemployment and health. Rebuilding a social network during a period of long term unemployment may contribute to minimize and balance the effects of unemployment on health status (Bartley 1994). Based on accumulating knowledge about the causal mechanisms on social determinants and health, public health has focused increasingly on questions of equity and social support as intermediate variables amenable to public health intervention.

If it is currently impossible to conceive predictive models linking social change to population health status on a large scale, it is even more the case for predicting a change in the health status of a local community undergoing social change secondary to the planning and implementation of a project. However the absence of coherent quantitative models in order to predict the overall impact of a project on the health of a given population does not biological effects. Members of the higher social and economic class present short term elevation of adrenaline and blood pressure, while members of the lower classes experience a chronic form of stress, leading to higher blood pressure, circulating fibrinogen blood levels and impairment of the immune system.

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mean that public health should not address the social determinants of health in environmental assessments. Public health professionals are able to estimate tendencies and types of effects of many social determinants on the health of a community.

> Public health has been defined as **"one of the efforts organized by society to protect, promote, and restore the people's health. It is the combination of sciences, skills, and beliefs that is directed to the maintenance and improvement of the health of all the people through collective and social actions. Public health activities change with changing technology and social values, but the goals remain the same: to reduce the amount of disease, premature death, and disease produced discomfort and disability in a population. Public health is thus a social institution, a discipline, and a practice."**
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Public health needs sufficient evidence in order to take action on health problems and determinants, it does not need absolute evidence. McKeown (1979, pages 128-130) provides the following thoughts on the degree of evidence, necessary for public health action :

- *Other examples could be cited in support of the view that action is often needed to protect and promote health in circumstances where the evidence is less than* mean that public health should not address the social determinants of health in environmental assessments. Public health professionals are able to estimate tendencies and types of effects of many social determinants on the health of a community.

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- *Other examples could be cited in support of the view that action is often needed to protect and promote health in circumstances where the evidence is less than*

> *complete. Moreover, in many cases it is questionable whether within the foreseeable future the evidence will be complete. To assess precisely the respective roles of diet, exercise and smoking in the causation of coronary artery disease, a massive human experiment would be needed, with division of a population into multiple experimental and control groups. Such an investigation would present formidable ethical, technical and administrative difficulties. Does this mean that no action can be taken in this and similar cases because the grounds, however suggestive, are not conclusive?*
>
> - *In the light of such difficulties I believe it will often be desirable to act on the basis of high, or even moderate probabilities, on what has been called 'a burden of prudence' rather than 'a burden of proof'. [...] it should be recognized that conclusive evidence of harm or benefit to health is often an unrealistic requirement.*

Current knowledge of the social determinants of health makes it imperative to integrate these aspects into the public health process of environmental assessments. Influencing known social determinants of health affected by projects is a valid and important public health action. The conceptual renewal process of health promotion and the New Public Health provides ample arguments and support to address the social determinants of health in environmental assessments (Banken 1998). Social assessment practitioners have developed a framework for identifying, predicting and managing social change secondary to the planning and implementation of a project. A public health approach to the social determinants of health should be integrated into the social impact assessment process.

Prediction, Social Learning and Sustainable Development

Prediction

Predicting the consequences of a project is one of the basic characteristics of environmental assessments. By providing predictions of consequences to the decision makers, the project can be modified in order to minimize the negative and maximize the positive consequences.

In the area of social impact assessments, this process of assessing the future social consequences of planned actions must be distinguished from the enterprise of making predictions of precise social events. It is possible to predict certain types of impacts and some likely patterns of response. This does not mean that the social assessor is capable of making exact quantitative predictions according to a cause/effect pattern.

> **Each action in an interaction sequence has, at best, only a modest predictability unless many parameters such as the relative power of participating groups remain essentially unchanged. As a result the probability of predicting a number of sequential interactive actions rapidly approaches zero.**
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> ***(Finsterbusch 1995, pp. 16-17)***

The use of the term predictive social impact assessment in the social impact assessment literature usually signifies the prediction of tendencies and types of impacts. It does not mean the prediction of a precise social event at a specific point of time.

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In order to better understand social impact assessment it is useful to compare social and biophysical effects of projects. Social consequences resemble biophysical consequences (Interorganizational Committee on Guidelines and Principles for Social Impact Assessment 1994, p 14) :

They can be valued as negative as well as positive
They can be of short or of long duration
They are dependent on the project setting
They are likely to be cumulative

However, social science generalizations can never achieve the law-like status of those in the physical sciences. Social systems are subject to the influence of conscious human beings who have the capacity to influence the system through individual choices. The future of social systems is open while the future of natural systems is causally determined.

The main difference between social and biophysical effects of projects is stated in the sociological saying : *What is perceived to be true, even if false, has real consequences* (Renaud 1994, p 317). Social impacts start with the very beginning of the project. Already during the planning stage perceptions of the project are evolving, personal or business decisions are made, tension between project proponents and opponents can diminish the social cohesion in the community. Biophysical impacts only start with the implementation of the project.

The accuracy of predictions in environmental assessments depend on many interrelated factors, like the quality of guidelines for producing the environmental impact statement, the appropriate timing in initiating the assessment, the availability of scientific knowledge and the use of scientific knowledge by consultants.

The first decades of environmental assessments have been marked by procedural and methodological problems. The lack of predictive accuracy has been typical of biophysical as well as social predictions. Among the 10475 environmental assessments conducted in the United States between 1970 and 1980, Culhane, Friesma et al. (1987) choose a sample of 151 environmental impact statements. They found that the predictions were either too vague to be verifiable or that they had only a rather weak predictive accuracy.

Boothroyd (1995) conducted a study to identify and evaluate the predictive accuracy of social impact assessments of Canadian megaprojects. The accuracy of the predictions was rather poor, positive impacts tended to be less than anticipated, as were negative impacts except for the impacts of hydroelectric megaprojects on native communities.

Gagnon (1994a) conducted an in depth post evaluation (evaluation research documenting the post implementation impacts) of the social consequences of an aluminum smelter. Her findings confirm the relatively poor accuracy of the initial predictions. Contrary to Boothroyd's metastudy, Gagnon found the real impacts to be more important than the original projections . Gagnon attributes this weakness in predictive social impact assessment to the concepts and methodological orientations. The initial social impact assessment used a causal model, predicting the social impacts on the basis of a quantitative social analysis and the project description. The quantitative social analysis favours organizational aspects of the community (infrastructure, constructions, land planning) and neglects the meanings, perceptions and social significance of these changes.

The scientific content and the accuracy of predictions are an important element in the environmental assessment process and they can be improved further. The limiting factors of the success and effectiveness of environmental assessments depend much more on procedural aspects like establishing standards for quality performance, upgrading processes like public involvement, considering cumulative effects and strengthening the practice of assessing policies, plans, and programs (Sadler 1996).

Social learning

The scientific prediction of types of impact and pattern of response is part of the social impact assessment process which integrates scientific aspects, public participation and interactions between the project proponent, the public and its different subgroups, government agencies and experts. The integration of scientific activities into a social dynamics is at the very heart of social impact assessment.

Biophysical impacts start with the implementation of the project. It is therefore possible to use the planning phase in order to adjust the project to minimize the negative and maximize the positive consequences. Social effects begin with the planning phase. Therefore they depend not only on the project characteristics but on the planning process itself. During the siting and planning process perceptions of the project are evolving, tensions between project proponents and opponents can diminish the social cohesion in the community, a hostile reaction to the project may coalesce the community opposition to a full scale NIMBY (Not In My Backyard). From an environmental stress perspective a proposed waste facility can be considered an invisible stressor and even may lead to greater psychosocial impacts than the visible stressor of an existing landfill (Elliott and Taylor 1996, pp 296-7).

A comparative longitudinal study has compared the project context, the planning process, the project characteristics and the social consequences of three waste site facilities in southern Ontario. Through the comparative study design it was possible to separate the actual impacts of the completed project from the siting and planning process. The authors conclude that the siting and planning process itself has a profound impact on the social

consequences of a project.

> **Actual or perceived community exclusion from site management and planning leads to a sense of disempowerment, distrust, and resentment. [...] It promotes and perpetuates adversarial relations between the community and the agencies responsible for the facility. Genuine involvement of community members in site management and planning can substantially prevent and reduce associated psychosocial distress.**
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Efficient social impact assessment has to start at the very beginning of the planning phase of a project in order to attain its goal of minimizing the negative and maximizing the positive consequences. To maximize its effectiveness social impact assessment has been conceived as an iterative process with interactions and transactions between the scientific experts, including the social assessors, the public and its different subgroups, the project proponent and gouvernment agencies. In this model of social impact assessment, public involvement becomes an integral part of the process. This iterative process can be considered as a collaborative or social learning process (Rickson, Western et al. 1990; Webler, Kastenholz et al. 1995; Daniels and Walker 1996).

The term social learning refers to social aspects of individual development and learning. In this perspective social learning becomes a central element of social change (Webler, Kastenholz et al. 1995, p 444-45). A study of social impact assessment of large-scale natural resource projects in Canada, Thailand and Australia has shown the need and consequences of a project.

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The term social learning refers to social aspects of individual development and learning. In this perspective social learning becomes a central element of social change (Webler, Kastenholz et al. 1995, p 444-45). A study of social impact assessment of large-scale natural resource projects in Canada, Thailand and Australia has shown the need and opportunity of transforming, through a social learning process, social impact assessment into a community empowerment process and by the same token increase community acceptance of otherwise contested projects (Gagnon, Hirsch et al. 1993).

In a social learning perspective scientific input and local community knowledge are used to foster mutual appropriation of the project consequences among the different stakeholders (groups of the public, the project proponent, the managers of the assessment process and others). The legitimacy of the final outcome is higher when stakeholders participate in a fair and open process (Webler, Kastenholz et al. 1995). This type of process addresses the social determinants of health through a systematic and proactive process. It is an efficient way of preventing and mitigating the negative psychological effects and maximizing the positive consequences of a project.

From a public health point of view, the social learning perspective is a strategy of health promotion aiming at social development and collective empowerment (Rissel 1994). It is therefore coherent with the health determinants and health objectives approach and should be considered as an efficient public health intervention.

Sustainable Development

The concept of sustainable development, has been made known through the World Commission on Environment and Development in 1987. It has been defined as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (World Commission on Environment and Development 1987). Through the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, sustainable development has become the internationally accepted principle for economic development, social development and

environmental protection. The social objectives of sustainable development comprise empowerment, participation, equity, poverty alleviation, social cohesion, population stability and institutional development (Goodland and Daly 1995).

The concept of environmental assessments started to be implemented with the passage of the United States National Environmental Protection Act (NEPA) of 1969. This groundbreaking legislation and its regulations explicitly included social aspects into the concept of the environment.

> **The human environment is to be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment. Agencies need to assess not only so-called direct effects, but also aesthetic, historic, cultural, economic, social, or health effects, whether direct, indirect, or cumulative.**
>
> ***(Interorganizational Committee on Guidelines and Principles for Social Impact Assessment 1994, p 13)***

This obligation to consider social consequences of projects left the choice of specific methodologies and the issues and objectives to be examined to the social assessment experts.

In the last decade, sustainable development has become the overall objective of the environmental assessment process (Sadler 1996). In order to be coherent with the social objectives of sustainable development, empowerment, participation, equity, poverty environmental protection. The social objectives of sustainable development comprise empowerment, participation, equity, poverty alleviation, social cohesion, population stability and institutional development (Goodland and Daly 1995).

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In the last decade, sustainable development has become the overall objective of the environmental assessment process (Sadler 1996) In order to be coherent with the social objectives of sustainable development, empowerment, participation, equity, poverty alleviation, social cohesion, population stability and institutional development should become the overall objectives of human impact assessment. However, this shift towards specific objectives of human impact assessment has yet to become the object of professional consensus or of legal obligations.

One of the major challenges of a sustainable development perspective to social impact assessment concerns the traditionally unequal distribution between the positive consequences on a regional and national scale and the negative consequences in the local community (Lee 1984). Social equity in sustainable development is not only intergenerational, but also spatial. Local needs and aspirations have to be respected and integrated into social impact assessment of projects (Gagnon 1994b).

Sustainable development places the human being in the center of all development, it is highly coherent with the health determinants approach of public health. The health determinants of ecosystem health, economic equity and social development become the overall objective of development. The traditional efforts of public health in favour of intersectoral action for health are transformed into collective efforts of all government agencies, non-government organizations (NGO's) and the private sector towards sustainable development of social, economic and environmental capital (Goodland 1994; Health Canada 1997).

Effectiveness of the Social Determinants in the Health Approach

After about a quarter of a century of environmental assessments, human health aspects are still frequently absent even for projects with significant human health impacts (Ortolano and Shepherd 1995). Part of the resistance to integrate health aspects into the project analysis may be explained by a perception by decision-makers that the environmental assessment process is already too long, too complicated and too costly (Dorais 1994). This perception questions the overall effectiveness of the environmental assessment process.

The effectiveness of a process refers to degree the process attains its goals or its objectives. This is the central theme of evaluation programs and evaluation research (Mohr 1995). The overall aim of the environmental assessment process concerns the prediction of future impacts in order to change a project, it's primary concern is not the evaluation of impacts once they have occurred. In order to judge the effectiveness of the environmental assessment process or of one of its components, like the health assessment, it is necessary to conduct specific studies.

The International Environmental Assessment Effectiveness Study (Sadler 1996) has been conducted in order to evaluate to which degree the environmental assessment process has resulted in better decisions, contributed to environmental objectives and how to streamline the process by improving decision-making towards the overall goal of sustainable development. They recommend different cost-effective measures to strengthen environmental assessment. A better integration of social consequences and health impacts figures among these cost-effective measures (Sadler 1996, p 275).

The World Bank has evaluated the effectiveness of their environmental assessment process in project preparation and implementation. The overall evaluation is very positive on the contribution of the environmental assessment process to decision-making, with only 15 percent of all projects that had undergone a full environmental assessment being rated in the low effectiveness category (World Bank 1997, p49).

These different studies addressing specifically the question of the effectiveness of an environmental assessment process attribute a very positive note for this prospective tool for sustainable development. No specific studies seem to exist to demonstrate the effectiveness of a determinants of health approach in optimizing the overall population health outcome of a given project. As a better integration of social consequences and health impacts has been identified as a cost-effective measures for improving decision-making (Sadler 1996, p 275), the integration of the social determinants of health into human impact assessment should be considered as a effective public health action.

It is very difficult to study the cost effectiveness of integrating a social determinants of health approach into the environmental assessment process. A great proportion of negative impacts on ecosystems and human beings generate external costs, being paid by society. Social determinants of health have emerged as one of the most powerful modifiers of population health, generating demand for health services which are paid through taxes. The effect of unemployment on health service costs may serve as an example of quantifying external costs of social determinants of health.

> **A cost analysis based on the population attributable risk approach established the cost of health care attributable to unemployment at $1,085 million in 1993.**
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Effective Strategies

Available knowledge on the effectiveness of social impact assessment permits to identify promising strategies for implementing the social determinants of health approach. These

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Effective Strategies

Available knowledge on the effectiveness of social impact assessment permits to identify promising strategies for implementing the social determinants of health approach. These strategies comprise a social impact assessment process which is issue-oriented, iterative and participative and a social learning process to enhance community involvement and social development.

Traditional planning assumed *local people will adjust to new technology or policies, and investigation of local customs, knowledge, and attitudes is irrelevant to the long-term success of projects and plans* (Rickson, Burdge et al. 1990, p 235). This paternalist approach has also been dubbed *DAD (Decide, Announce, Defend), where community residents are involved post facto in the siting process through information dissemination, public meetings, and environmental assessment hearings* (Elliott and Taylor 1996, p 290). This traditional approach to project planning has met increasing local resistance, known as NIMBY (Not In My Back Yard). Social impact assessment as a social learning process has not only been shown to be the most efficient way of minimizing the negative and maximizing the positive social consequences of a project, but it has gained increased acceptance over the last decade as the only means of avoiding local resistance to some types of projects.

The issue-oriented or stakeholder approach permits the identification and focusing on key issues of the social consequences of a project. The immediate goal of social impact assessment is the best decision and management, rather than the generation of new knowledge. The encyclopedic or laundry-list type approach to social impact assessment, where investigators attempt to research almost every aspect of community life to be affected by a plan or project, has shown to produce a plethora of data, unable to support decision-making. In social impact assessment the aim is not to produce as much data as possible, but as little data as necessary (Taylor, Bryan et al. 1995, p 123). The environmental assessment process has been conceived as an action-forcing device, legally forcing decision-makers to take environmental concerns into account. The issue oriented approach in social impact assessment is a decision-forcing device, forcing the social assessor to produce social science knowledge relevant to the decision process, favouring social development and equity.

Participation is central element in all components of any assessment process. The identification of key issues in the scoping phase and of stakeholders who are going to win or to lose is impossible without the participation of the social groups being affected. The fieldwork of social profiling is dependent on the participation of the community. Monitoring, mitigation and management is unthinkable without a very active participation of the different groups, usually through a negotiation process. Participation of the affected community is not to be seen as a unavoidable constraint and obstacle for obtaining the consent of the community, but as an transactive means of obtaining (Burdge and Robertson 1990) and communicating information on social effects. Participation becomes the central strategy for social development.

Modeling the social determinants of health approach on the issue-oriented, iterative and participative social impact assessment process, conceived as a social learning process, signifies a shift from a health protection to a health promotion framework in environmental assessments. Public health no longer aims at protecting the public from toxicological and microbiological hazards of projects, but it enhances the overall contribution of a given project towards the improvement of community and population health.

Conclusions

- Current knowledge of the social determinants of health makes it imperative to integrate these aspects into the public health process of environmental assessments.

- A public health approach to the social determinants of health must be coherent with the traditional social assessment process.

- It is possible to make accurate prediction of tendencies and types of effects on the social determinants of health.

- Current knowledge on the direct and determinant influence of social determinants on population health does permit an estimation of tendencies and types of effects of social change on population health status.

- The state of knowledge does however not permit to build predictive models linking social change to population health status for specific projects. Public health action on the social determinants is possible without exact knowledge of causal pathways.

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

DECEMBER 1999

This document has been divided into a series of files for easier downloading from our web site.

Part 7 of 9

Biostatistical Concepts and Methods

Chapter G Contents

Introduction

Biostatistics in Health Impact Assessment

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- **Estimation**
- **Hypothesis Testing**
- **Detecting Statistically Significant Effects**
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  - ***Regression analysis***
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Special Topics

- **Estimating Potency**
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Difficulties, Challenges

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Introduction

Biostatistics are used in Health Impact Assessment (HIA) and Environmental Impact Assessments (EIA) to quantitatively describe present health, social and economic status and the predicted impacts of the project being assessed. But what are statistics and why and when do we use them?

A *statistic* is a value which summaries some quantitative attribute of the data. For example, the mean is the average value of the data.

A statistic is a value which summarizes some quantifiable aspect of data. Often the data we observe are a subset or *sample* of a much larger *population* of data. Samples are simpler and less costly to study than populations. However, the objective of the study is usually to make statements about the population. This can be accomplished with samples as long as the sample is *representative* of that population. The key is to understand how the sample relates to the population. There are many, often infinite ways of selecting a sample. Thus, any quantified statements about the sample become *probabilistic* statements about the population. Selecting the sample, analysing the data, and drawing inferences about the population is a complex activity which is the subject of the discipline known as *statistics*.

Definition:
Statistics **is a discipline dealing with methods and rules of obtaining data, analysingandsummarizing it, and drawing inferences from data samples by the use of probability theory. It is governed by the** ***laws of probability*****, and involves numbers and randomness but requires** ***logic*** **and*****problemsolving*****.**

Useful properties of statistics are that they are representative of the population and that they are reproducible to a certain degree. Representativeness is accomplished by randomly selecting a sample from

The entire set of objects that are of interest is called a *population*.
A portion of a population is called a *samplo*.

the population. For example, in cleaning up a hazardous waste site, the concentration of contaminants throughout the site is valuable information. However, to measure the concentrations at every possible location is not practical so a sample of locations is selected. This sample, if carefully chosen, can provide statistics that are representative of the overall contamination of the site. Some kind of randomization in the selection of the sample, whether it is unrestricted or restricted by certain constraints, is the basis of ensuring representativeness. Statements can even be made about the confidence one has that the sample statistic represents the theoretical population statistic using confidence intervals.

***Randomization* is key to selecting a sample which is representative of a population.**

Measurements on a population of items under study vary; that is, they are not a predictable constant. Thus, there is an underlying *distribution* for the measurements of the population. A *histogram* of the selected sample of measurements provides a reasonable picture of the population distribution. One of the more common distributions is the Normal distribution which is symmetric and bell-shaped.

Distributions are summarized using key statistics. For example the normal distribution can be completely summarized by the mean and variance; that is, the population distribution is estimated by estimating the mean and variance of the sample of measurements. Summarizing population distributions by a type of distribution and the statistics that specify the distribution allows us to make comparisons among populations.

Selecting a representative sample is not always straightforward. Constraints may dictate restrictions on the way the data is collected. Special sampling designs are developed in order to make the most effective inferences in the most efficient way. In the laboratory setting factorial, randomized block, and randomized incomplete block designs are examples of standard protocols which are selected depending on the objectives and

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The application of statistical methods usually requires that assumptions be made about the data. For example, to use the t-statistic for testing the hypothesis that the mean of a population equals zero is valid only if the data come from the same normal distribution and are independent of each other. If the methods are applied without consideration of the underlying assumptions upon which they are based, erroneous and misleading conclusions could result.

As the complexity of the sampling protocol and the hypotheses to be tested increases, the complexity of the methods for analysing the data increases as well. Statisticians are specifically trained through university programs to learn the proper application of complex statistical methodology highlighting the fact that statistics is an important scientific field of study. Statisticians with Masters degrees and Ph.D.s are trained to develop new and adapt old methods when required.

Some training in statistics for non-statisticians involved in HIA is recommended in order to understand the concepts, though it may not be necessary for a researcher or evaluator to know how to apply the methods themselves. Sometimes it is only necessary to know when a statistician should be consulted. Training can range from short, introductory courses to graduate level degree courses. Many disciplines such as toxicology, psychology and economics require at least one introductory statistics course in their degree program.

Statistical analysis has become much more accessible to non-statisticians with the advent and continual expansion of computing resources. Easy to learn, use and inexpensive, programs are now available on personal computers which are capable of relatively sophisticated analyses. Some are easy point-and-click programs while others are highly advanced programming languages such as the Statistical Analysis System (SAS, 1990) and S-Plus (MathSoft, 1990). We reemphasize however, that care must be exercised in using these programs in order to ensure the integrity of the results.

Biostatistics in Health Impact Assessment

Opportunities for using statistics arise in all aspects of HIAs. Common applications include: evaluation of exposure; evaluation of fate of contaminants; evaluation of risk; projected costs to mitigate impact; evaluation of baseline exposure versus predicted future exposure; estimation of magnitude/impact; estimation of population impacted; quantification of health indicators; and levels of toxic chemicals in human tissues (see vol. 1).

There are several advantages to using reliable statistics in HIA:

- Using appropriate statistical methodology enhances the credibility of the results;
- Sampled data can be extrapolated to make inferences about a population and a level of confidence determined for the extrapolation;
- Statistics enables the assessment of variability and highlights uncertainties in the data;
- "Averages" can be estimated in light of the shape and location of the sampling distribution;
- Results can be interpreted in light of estimated variability.

A Type I error is said to have been made if we infer that there is a real difference between the two samples, while in fact the observed difference is due to chance only.

[Kennedy and Neville, 1974.]

There are also limitations to the utility of statistics.

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answers will be provided. Statistics are probabilistic in nature and therefore carries with it a probability of making errors (TYPE I and Type II).

- The statistics are only as good as the data. Potential sources of error include: the data are not collected to address the specific objectives of the study; the measurement technology is unreliable or highly variable; other confounding factors lead to misinterpretation of the results.
- Statistical analysis is highly dependent on assumptions. If one or more of the assumptions are invalid, then the conclusions could be erroneous.

A **Type II** error is said to occur if we conclude that there is no real difference between two samples, while the difference does in fact exist.

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Statistical Analysis

Describing Data

Before analysing data, the structure of the data and how it was collected is determined. There are two key questions:

(1) What was the experimental or survey design?
(2) What kind of data was collected?

What is the experimental or survey design?

A well-designed experiment has many advantages. It can facilitate the use of valid and efficient statistical procedures. Results are often easier to analyse and interpret and more comparable with those of other studies.

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Statistical principles of experimental design include randomization, efficiency, blocking, and structure. Randomization provides statistical independence and validity. It insures that nothing distinguishes the treatment groups other than the treatments themselves. For example, in animal toxicology experiments, to conduct proper randomization, treatments must be assigned randomly to animals and animals randomly assigned to cages. Blocking refers to blocks of experimental units. For example, if some experiments were done on one day and some on a different day, then day is a block effect. Structure refers to how the experimental units were layed out such as number of factors or time sequences for experimental units.

What kind of data was collected?

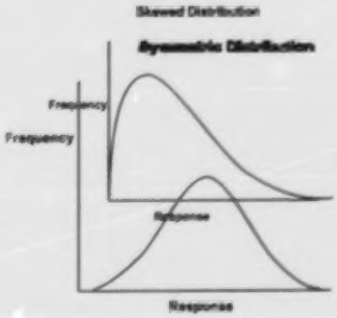
Many end points may have been collected during the course of the experiment. There are three types of outcomes:

- continuous
- proportions
- count

Examples of continuous endpoints are body weights, feed consumption, clinical chemistry, haematology, urinalysis results, and organ weights. Proportions arise when the number of animals with tumours in a group of animals is of interest. Examples of count endpoints are white blood cell counts and number of mutations in a mutation assay.

It would be convenient if there was a one-size-fits all statistical analysis, but this, unfortunately, is not the case. Procedures that may appear to fit many situations may not be the most efficient tests and lack power to detect effects. Thus, great care must be exercised in choosing the right analysis. The experimental design and the type of data determines the appropriate statistical analysis.

Estimation



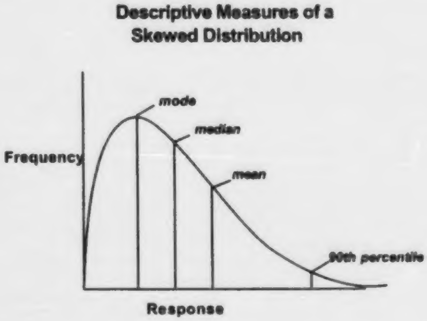
A statistic is a function of the data meant to summarize a particular aspect of the distribution of the data which can be symmetric, skewed, bimodal or some other shape. For a normal distribution, if the mean and the variance are known then the entire distribution can be reconstructed. The true mean and variance may be unknown but can be estimated using the statistics, the sample mean and variance which are calculated using the data. The mean is a measure of central location for the normal distribution. Other measures of central location are the median, mode and geometric mean. Other statistics which help describe a distribution are percentiles (or quantiles) and a variety of measures of variability such as the variance and the range of data.

Definitions of commonly used summary statistics

Sample Statistic	Definition
Mean	**sum of all data divided by the number of data points (n)**
Median	**data point where 50% of the data have smaller values**
Geometric mean	**product of all data to the power 1/n**
Variance	**sum of squared deviations of each data point from the mean, all divided by number of data points minus one**
Standard deviation	**square root of the variance**
Standard error of the mean	**square root of the variance divided by the number of data points**
nth Percentile	**The data point where n% of the data have smaller values**

n% Confidence interval for the mean	**The confidence interval covers the true mean, n% of the time.**

An issue that often arises in exposure assessment is determining a meaningful summary measure of exposure if the data come from a skewed distribution. If there are a small number of very large values, a frequent occurrence in exposure data, then the mean may be greatly influenced by these points and thus may not accurately summarize the central tendency of the distribution of data. The median and the geometric mean are more insensitive to these large values. A decision about what measure to use will be based on the objectives of the assessment.



Hypothesis Testing

Making comparisons among populations is done using a rigorous statistical decision theory approach. In the classical (Neyman-Pearson) approach, a *null hypothesis* is constructed then tested against an *alternative hypothesis* using a *test statistic*. The null hypothesis is always stated as no difference or no effect. The alternative hypothesis is stated as all possible alternatives.

Example: The null hypothesis for testing that the means of two populations, μ_1 and μ_2, are equal is written as

Ho: $\mu_1 = \mu_2$

which is tested against the alternative

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This is a two-sided test. For a one-sided test, the $\neq$ will be replaced with < or > as appropriate.

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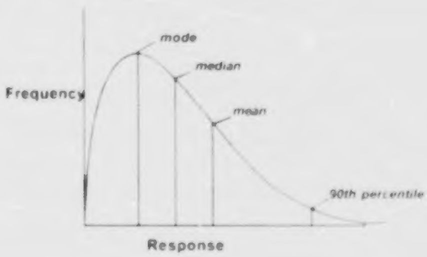
Descriptive Measures of a Skewed Distribution



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Detecting Statistically Significant Effects

Comparisons among groups

Methods for establishing statistical significance of effects depend on the type of data.

Continuous Data

Statistical tests depend on a number of assumptions that are made about the data. It is important to ensure the validity of these assumptions in order to ensure the validity of the statistical test. Suppose that 10 animals were exposed to a substance and there were 4 such exposure levels. The objective was to determine if there was a detectable change in weight. Here weight is continuous. Analysis of variance (ANOVA) is usually used to determine if there are statistically significant differences between the means of the four dose groups. However, there are three assumptions that must be made about the data to ensure the validity of the analysis of variance procedure.

(1) the data are independent from one another,
(2) variance of the measurements are equal, and
(3) weights are normally distributed.

Independence can usually be ensured if strict randomization of the allocation of animals to treatments is carried out. Normality would be a characteristic of the data. This can be validated in a number of ways. If the data come from the same normal distribution then a histogram of the data will have a symmetric, bell shaped curve. One common misconception is that the raw data from an experiment should have this shape if they are from a normal distribution. This is not necessarily true if there are differences among the means of the dose groups. In this case, a histogram may appear bumpy indicating more than one mode in the data. To check out normality, the group mean can be subtracted from the all the data within that group. A histogram of the resulting *residuals* should then appear bell-shaped with only one mode if the data come from normal distributions.

Normality of Residuals

- **Histogram should be bell-shaped, not skewed**
- **Plot of residuals vs predicted values should have equal variability across predicted values**
- **Test of normality should not be significant**

Sometimes, after adjusting for the means, the residuals appear to be skewed with long tapering tails. This is usually the case for concentration data. Since the ANOVA procedure requires normality, the data needs to be transformed to normality before the test can be done. Applying a log transformation to concentration data often normalizes the data. Other types of data may require alternative transformations. Once normality is achieved, statistical tests are then conducted using the transformed data. If the sample sizes are large, then it is less important to achieve normality since the distribution of the means tends to become increasing normal as the sample size increases.

Provided the assumptions discussed above are applicable, the Student's t-test is used to test the hypothesis that two groups means are equal. To test the equivalence of the means of more than two groups, ANOVA is used.

Significance tests for equality of means with normal data

Test	Description	Assumptions
T-test	**Equality of means of two independent groups of data**	• **normality** • **independence of all data** • **homogeneous variance**
Paired t-test	**Equality of means of paired groups of data. Equivalent to a one-sample t-test on the differences between the pairs.**	• **normality** • **independence of all pairs of data** • **homogeneous variance**
ANOVA	**Equality of means of more than two independent groups of data**	• **normality** • **independence of all data** • **homogeneous variance**

The ANOVA procedure will establish that at least two means are statistically different from each other, but it will not indicate which means are different. To determine which means are different, multiple comparisons between the means are conducted. This is not as simple as performing pairwise t-tests between the control group and each dose group since the significance levels for the hypothesis tests are no longer valid. Instead, a multiple comparison method can be used. The appropriate method for the comparison of the control to all others individually is Dunnet's test. Duncan's Multiple Range test, another multiple comparison method is appropriate for pairwise comparisons among all possible pairs.

Multiple Comparisons		
Dunnet's	**Compare many treatment means to a control**	• **normality** • **independence** • **equal variances**
Duncan's	**Compare all possible pairs of treatments**	• **normality** • **independence** • **equal variances** • **equal group sizes**

Categorical Data

Categorical data arise when the response can be categorized into one of a small number of categories. For example, an animal in a carcinogenicity study is classified as either having a tumour or not having a tumour. The number in each category can then be counted. An example of such data is given below.

Binomial Data		
Group	Number of Animals with Tumors	Total Number of Animals
Control	**1**	**100**
Test	**4**	**50**

Note that the number of animals without tumours is the total number of animals minus the number of animals with tumours. Fisher's exact test is used to compare the proportion of animals with tumours in the control group to the proportions in the test group.

There are studies in which outcomes fall into more than two categories such as eye irritation and dermal irritation tests in which a score is given to the degree of irritation. For such set-ups, more sophisticated analysis is required. The SAS package contains the CATMOD procedure which will handle a wide range of analyses of categorical data (SAS, 1990). Shoukri and Edge (1996) have a good discussion of some of these techniques.

Count Data

Count data arise when the number of outcomes is of interest and there is no maximum number of outcomes. The number of mutations in a mutation assay is an example. Other examples of count data are white blood cell differential data and nucleated red blood cell counts. Counts have a Poisson distribution. A simple approach for analysing count data is to compute the square root of each count then use normal test techniques as discussed in Section 2.2. This works quite well when the counts are relatively large. If the counts are small, more sophisticated methods using the Poisson distribution allowing for over-dispersion due to experimental error would be more appropriate.

Non-parametric tests

The normality based test for continuous data is called a *parametric test* since the data is assumed to arise from a known distribution, namely the normal distribution. Sometimes, however, the data do not arise from a known distribution. For example, with continuous data, there may not appear to be any suitable normalizing transformation. The only assumption that may be reasonable is that the shape of the distribution for each exposure group is similar, but may be shifted. In this case, nonparametric tests can be used to test for significant shifts in location.

The Wilcoxan rank-sum and the Mann-Whitney U tests are used to test if two groups have the same location parameters. The Kruskal-Wallis test is used to test for differences among more than two groups. These tests are all based on the ranks of the data rather than on the data themselves.

Regression analysis

When the response is of the continuous type, for example, weight or concentration, and of interest is the relationship between the response and a second continuous variable, for example, height, then regression analysis is used to determine if there is a significant relationship and the form of the relationship. A simple linear regression where there is only one input variable is expressed as:

$$y = a + \beta x + e$$

where y is the response, x is the input variable, a is the intercept parameter, ß is the slope parameter and e represents an error term which is often assumed to have a normal distribution with 0 mean and some unknown variance. The slope parameter can be increasing, decreasing or remain level. The intercept parameter is the average value of y when x is zero.

The simple linear regression situation can be generalized to include more input parameters, known as multiple regression. It could also include categorical input parameters. A mixture of an analysis of variance and regression set-up is called a general linear model. One of the requirements for the input variables is that they are independent of each other. If they are not, then multi-colinearity occurs and the analysis may not produce well- defined results.

The above assumes that the response is linearly related to the input variables. If this is not the case, then non-linear regression must be applied. For example:

$$y = a \exp(-\beta x)e$$

is a common non-linear expression. Non-linear regression analysis would normally be performed using a statistics analysis package. In this case however, linear regression could be used if the model was transformed by taking the logarithm of each side of the equation so that:

$$\log y = \log a - \beta x + \log e.$$

The analysis is performed on the new log y response variable, an easier approach than non-linear regression which is a technique requiring advanced knowledge of statistical procedures. The difficulty in analysing transformed data is in the interpretation of estimated models.

Once again, assumptions made about the data must be valid before performing the analysis. Linearity, normality, independence and homoscedasticity can be checked out on the residuals of the analysis. Neter et al (1990) have a comprehensive discussion of many aspects of general linear models.

Regression analysis can also be performed on categorical response data. The technique called logistic regression is explained more fully in Shoukri and Edge (1996). SAS contains a logistic analysis procedure (SAS, 1990).

Multivariate analysis

Multivariate analysis is applicable when there are several responses to analysis and the objectives are not only to determine relationships between input variables and responses but those amongst the response variables. Common multivariate techniques include principle component analysis, cluster analysis, factor analysis, and multi-dimensional scaling. A complete discussion can be found in Johnson and Wichern (1992). Computer programs such as SAS are particularly useful (SAS, 1990).

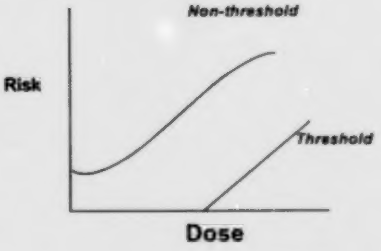
Special Topics

Estimating potency

Threshold toxicants

Guidelines and priorities are established on the basis of potency estimates of toxicants. There are two types of mechanisms for toxic effects that determine the method for estimating potency. Some effects are believe to have a threshold exposure below which the effect will not appear. Others such as genotoxic carcinogens, are presumed to have no such threshold.

Dose - Response Shapes



The figure to the right shows theoretical dose-response relationships for threshold and non-threshold toxicants.

The concept of a threshold centers around the assumption that the dose level determines whether or not a pathological effect will occur upon exposure. Ideally, for the purposes of risk management, one would want to estimate this threshold. However, these thresholds may vary among individuals. In the uncertainty factor approach to risk assessment for threshold toxicants, a no observed effect level (NOEL) is selected based on a dose-response experiment in animals. Due to uncertainties of interspecies extrapolations from test animals to humans, and because of the individual variability in human sensitivity to the effects of toxic agents, safety or uncertainty factors (UF) are introduced. Thus, for example, an acceptable daily intake (ADI) may be computed by dividing the NOEL by the uncertainty factors UF, that is:

$$ADI = NOEL / UF$$

Uncertainty factors range from 1 to 10 for each factor, 10 being the common default value. Other safety factors are added to account for use of a LOAEL instead of a NOAEL and to account for inadequacies in the data base.

There are a number of criticisms of the uncertainty factor approach. First, the observed no effect level depends on the sample size. For example, a response of 0 in 10 means something different than a response rate of 0 in 1000. Moreover, the approach assumes that a threshold dose exists below which no adverse effects will occur. These thresholds may vary from animal to animal so that a minimum threshold would need to be estimated.

A benchmark dose approach has been gaining recognition as a method which could address some of these difficulties. This method involves modelling the dose-response curve then estimating the lower 95% confidence limit on the dose corresponding to a small increase in risk over the background rate.

The benchmark dose approach can be applied to either quantal or continuous responses.

Type of data	Model	Model equation
Quantal	**Linear regression**	$P(d)=c+(1-c\{1-\exp[-q_1(d-do)]\}$
	Multistage	$P(d)=1+\exp[-q_1(d-d_o)-q_2(d-d_o)^2- \ldots -q_k(d-d_o)^k]$
Continuous	**Linear regression**	$m(d)=c+q_1(d-d_o)$
	Polynomial regression	$m(d)=c+q_1(d-d_o)+q_2(d-d_o)^2+ \ldots +q_k(d-d_o)^k$

Other curve fitting methods are possible.

For quantal data, the benchmark dose d is that dose with produces a specified extra risk of:

$$\frac{(P(d) - P(0))}{(1 - P(0))}$$

where *P*(0) is the value of the model equation *P*(*d*) when dose is zero. For continuous data, the benchmark dose is that which produces the specified extra response:

$$\frac{m(d) - m(0)}{m(0)}$$

A safety factor is then introduced to bring the predefined benchmark dose from 1% -10%

down to a level of "acceptable" risk. For a more complete discussion of the benchmark dose, see McColl (1990, p.23).

Non-threshold toxicants

For non-threshold toxicants, it is assumed that any exposure carries with it a probability of a response so that the exposure response relationship can be modelled with a smooth curve that approaches background rates as the exposure levels get smaller and smaller. This raises the question of how to express risk.

For evaluation of the Priority Substances under the Canadian Environmental Act (CEPA), the objective of the quantitative risk assessments was to provide a ranking of carcinogens. To do this, the lifetime exposure which yielded a 5% increase in risk was computed directly from the exposure-response relationship. This was combined with estimated exposure of the general Canadian population to obtain an exposure potency index for each substance. The result indices could then be used for ranking.

Other programs such as hazardous wastes and drinking water focus on setting guidelines. For these programs, it is important that enough information is available so that decisions can be made about potential remedial actions. Traditionally, excess risk would be estimated at low doses from the dose response curve.

For both objectives, risk is estimated by modelling the toxic response as a function of exposure. Krewski and VanRyzin (1981) discuss and compare a number of models which fall into two categories. The statistical or tolerance models are based on the assumption that an individual selected at random will respond at date d with probability such that:

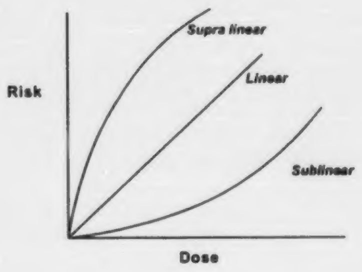
$$P(d) = Pr(\text{ tolerance} \leq d) = F(a + b \log(t))$$

These models include the probit, logistic and extreme value models.

Stochastic or mechanistic models are based on the assumption that a response is induced as a result of the random occurrence of one or more biological events. For instance, for the one-hit model, a response will be induced after the target site bas been hit by a single biologically effective unit of dose within a specified time interval. For the multi-hit model it is assumed that a response may induced after multiple hits. The multi-stage model assumes that the induction of irreversible self-replicating toxic effects is the result of the occurrence of a number of different random biological events, with the age-specific rate of occurrence of each event linearly related to dose.

Other regulatory programs focus on determining cancer risk at ambient levels of exposure. Ambient levels are usually much lower than experimental exposure levels in animal bioassays. Exposure-response models are derived based on these relatively high exposure levels necessitating extrapolation of risks at higher levels to risks at lower levels. However, these models are sensitive to the experimental exposure groups since the shape of the curve at the low levels is unknown.

Dose-Response Shapes at Low Dose



Multistage model

The multistage model is used by the USEPA and other regulatory agencies for estimating cancer risk. It is based on the probability *P*(*d*) of a tumour occurring following an exposure to a dose d at a fixed time t taking the form:

$$P(d) = 1 - \exp[-ct^k \sum_{i=0}^{k} (q_i d^i)]$$

where k is the number of stages assumed in the carcinogenic process. As the dose levels get smaller and smaller, the excess risk becomes approximately linear in dose. The 95% upper confidence limit is then computed and used as the low dose slope factor. The inverse of the slope is called the unit risk. The method is referred to as the Linearized Multistage (LMS) method.

Robust linear modelling

A number of problems were pointed out with extrapolating risks to ambient levels using models developed at relatively higher dose levels. Krewski et al (1991) developed a method (called the *model free extrapolation method* (MFX) or *robust linear modelling)* which addresses some of these concerns. The only assumption required by this method is that the dose-response curve is linear at low doses. Consider a bioassay with t+1 dose groups, including a control group. Estimate the probability of a response at each dose group by $pi = r_i/n_i$ where r_i is the number of animals in the ith dose group with the response and n_i is the number of animals in the ith dose group. Compare the p in the control group to the p in each dose group using Fishers Exact test at the 5% level of significance. Then, calculate the upper 95% confidence limit on p for each dose group before the first significant dose group and the lower 95% confidence limit on the p for the control group using exact binomial intervals and 5/(t+1) as the significance level according to the Bonferoni inequality. Calculate the slope of the line between these upper and lower confidence limits and select the smallest slope as the risk factor.

The strengths of the MFX method are that no model is assumed that may greatly influence the low dose extrapolation and that a reasonable degree of confidence exists that the true risk is below what MFX produces. Weaknesses include the fact that not all the data is used in the estimation of potency at low doses. Krewski et al (1991) show that the median ratio of the MFX to LMS estimates of the low dose slope was 1.3. Thus MFX gives somewhat higher slopes than LMS. In 443 of the 572 experiments, the ratio was within a factor of two.

The cancer risks estimated using standard methods are based on experimental exposure which may be administered intermittently though consistently throughout the lifetime of the animal. In order to obtain the risk associated with a constant average daily dose in mg/kg bw (body weight in grams)/day, the exposure must be adjusted. For example, say in an inhalation study, mice were exposed to concentrations in air for eight hours a day, 5 days a week for 92 weeks. The standard lifetime of mice is considered to be 104 weeks. To convert the exposure to constant exposure, the intermittent concentration is multiplied by a scaling factor as follows:

$$\text{constant exposure conc.} = \text{experimental conc.} \times (5/7) \times (8/24) \times (92/104)$$

Sometimes the experiment does not end at the standard lifetime of the animal under study. If the experiment ended early, the number of animals with tumours will probably be lower than if the experiment had been allowed to run to standard lifetime duration. In making comparisons with other carcinogens, the potency may seem lower. Experiments suggest that the tumour rate increases more rapidly than linearly with age and thus adjustment of the tumour rate by a factor f^2 or f^3 where:

f = time animals are on test / standard lifetime

is appropriate.

Sometimes exposure to a substance is not constant nor consistent over time. For example, infants and children may be exposed to higher amounts of pesticide residues that may be found in apple juice on a mg/kg bw/day basis than adults. Murdoch, Krewski and Wargo (1992) discuss this issue for the multistage and two-stage birth-death mutation models. They found that approximating lifetime risk on the basis of lifetime average daily dose may underestimate or overestimate risks depending on the exposure pattern.

Animal to human extrapolation

Animals used in toxicology experiments are smaller than humans and usually have higher metabolism rates. Therefore often the body surface area is used as the basis for extrapolation since it is believed to reflect more differences in metabolism than body weight. It is first assumed that the different species are equally sensitive on a basis of dose per unit surface area. A commonly used conversion factor is then:

$$\text{interspecies adjustment factor} = 3(70/w)^{1/3}$$

where 70 kilograms is the standard body weight of a human and w (in kilograms) is the standard animal body weight for the particular species used in the study.

There are other conversion factors which are advocated and can be written using the general form:

$$\text{potency} = a \times (\text{body weight})^b$$

where b takes on different values (see table below)

b	Interspecies Extrapolation Based On
1	body weight
2/3	body surface area
3/4	metabolic rate

4.2 Probabilistic assessment

Exposure and risk assessment in HIA is subject to many uncertainties. For example, risk is often estimated based on animal toxicology studies. These studies are conducted according to strict protocols on homogeneous populations of rodents. Extrapolating risk from rodents to humans is highly uncertain. In the absence of mechanistic information to the contrary it is assumed that humans will have the same risk as the rodents. That this is not always the case has been borne out by a number of studies which show that effects displayed in some species of rodents are not observed in others.

Additional sources of uncertainty arise from the extrapolation from the high doses used in laboratory studies to the lower levels in exposure experienced by humans; when toxicological results obtained under one route of exposure (oral, inhalation, dermal) are extrapolated to another; or when results of subchronic studies are used to estimate thresholds for chronic effects. Epidemiological data on exposed human populations can also be subject to considerable uncertainty when retrospective exposure profiles are difficult to construct, particularly with chronic diseases such as cancer for which exposure data many years prior to disease ascertainment are needed. Even prospective studies have large uncertainties. For example, in dietary studies both recall and food diaries can be subject to error. Disease diagnoses are subject to error as well.

Point estimates of risk in combination with conservative assumptions have historically been the way of expressing risk. However, the point estimates are based on highly uncertain data. By focussing on single summary estimates, it is possible to lose sight of the fact that such estimates are more properly viewed as upper limits rather than best estimates.

A more complete characterization of risk using uncertainty analysis can help us better understand the role of uncertainties in the overall risk and exposure estimates. The results can be summarized in the form of a distribution of possible risks or exposures to take into account as many sources of uncertainty and variability as possible. Morgan, Henrion, and Small (1990), NRC (1994) and Bartlett et al (1996) contain more detailed discussions of uncertainty analysis.

In an example, Hoffman and Hammonds (1994) used a multiplicative risk model to estimate the hazard quotient for a population of individuals potentially exposed through the ingestion of contaminated fish. The risk R is expressed as:

$$R = X_1 \times X_2 \times (X_3)^{-1} \times (X_4)^{-1}$$

where X_1 is the concentration of the contaminant in fish, X_2 is the ingestion rate of fish, X_3 is the body mass of a human and X_4 is the reference dose. The overall uncertainty distribution for R is developed by first estimating distributions for the input variables, X_1,

X_2, X_3, X_4, sampling from each of the input variables using Monte Carlo analysis, inputting the sampled values into the risk equation and computing the resulting R. This is repeated thousands of times to develop a sampling distribution for R. Monte Carlo analysis, though convenient and easy to use applying programs like Crystal Ball and @Risk, needs to be applied carefully to ensure the integrity of the results (Burmaster and Anderson, 1994).

Rai et al (1996) stress the importance of distinguishing between inherent variability in the input parameters and uncertainty resulting from a lack of knowledge. In the example above, the authors assume that X_4 is subject to only uncertainty, X_3 to variability and X_1 and X_2 to both uncertainty and variability. Distributions are developed for each component and then applied using Monte Carlo analysis. The impact of the various sources of variability and uncertainty can then be assessed individually or together.

Difficulties, Challenges

There are a number of difficulties and challenges associated with utilizing biostatistics to ensure evidence-based decision making.

- The complexity of the analysis can require an in-depth understanding of statistical concepts in order to be properly utilized or reviewed. The more complex the data acquisition protocol, the more complex statistical procedures needed for analysis.

- Some simple statistical methods can always be applied but they must be interpreted in terms of the way the data was collected.

- The comfort level in chosen statistical methods can be improved by obtaining training in concepts and consulting with experienced statisticians when necessary.

It is not always necessary to consult a statistician; it is more important to understand the concepts enough so as to know when to consult one.

- It is best to consult a statistician who is familiar with the types of statistical methods utilized in HIAs. For example, specific methods are utilized for developing risk factors. An understanding of the limitations in the data upon which these risk factors are based is essential to their appropriate interpretation.

Conclusions

- Statistical methods can enhance the credibility of results.
- They also provide a good indication of variability associated with the data.
- Care must be exercised in selecting methods of analysis and in the subsequent interpretation of the results.
- Knowing when to consult a statistician is helpful. A statistician with experience in HIA/EIA would be most helpful.

Resource materials, persons, organizations

Learning tools: Basic textbooks for non-statisticians, introductory courses, multi-media CD ROM.

There are many fine textbooks available which explain in detail basic statistical concepts. It is best to focus on textbooks written for non-statisticians since those for statisticians tend to be highly technical in

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language and presentation. It is highly recommended that a course in statistics be taken before any self education is attempted. Statistics is built on difficult concepts of probability which are easier to learn in an interactive environment.

Courses and textbooks can provide the highlights of statistical concepts but cannot possibly teach the entire field of statistics since the field is so rich. As stated earlier, statistical methods always depend on making assumptions about the data. Statisticians are trained to recognize these assumptions and to chose methods accordingly or develop/modify methods as needed. If the assumptions are ignored, then errors in conclusions could result. Errors range from inconsequential to very serious which could, for example, lead to costly decisions about mitigation where such action may not be justified if the data had been analysed correctly.

Consulting with a statistician in your organization at appropriate times can help avoid these costly mistakes. If a statistician is not available in your organization, there may be some available at the local University or in a consulting firm. The statistician is more valuable if they have developed an understanding of the types of data and issues in HIA. For example, they should have some experience in exposure modelling and toxicological study design.

Many computer programs are also available which perform statistical analyses. Spreadsheet programs such as Lotus 1-2-3, Excel, and Quatropro have regression analyses, plotting capabilities, and other statistical functions in addition to their spreadsheet capabilities. Other programs are designed specifically for statistical analysis (such as SAS, SPlus, SPSS, etc.) Add on programs such as Crystal Ball (Decisioneering, 1996) do simple Monte Carlo analyses. Interactive multimedia CD ROMs provide courses in statistics such as ActivStats (Velleman, 1998) .

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

DRAFT

DECEMBER 1999

This document has been divided into a series of files for easier downloading from our web site.

Part 8 of 9

Role of Occupational Hygienist within EIA

Chapter H Contents

Occupational Health Risks in Health Impact Assessment

Facets of, and Professional Disciplines in, Occupational Health

Occupational / Environmental Hygiene - History, Concepts, Precepts and Definitions

Occupational Disease and its Prevention; OELs as a Tool

Prospective Occupational Hygiene Applied to HIA - Tools and Techniques

Pitfalls of Occupational Hygiene in HIA

Guidelines on the Selection of an Occupational Hygiene Specialist

- ***The Need***
- ***Meeting the Need***
- ***Accredited Occupational Hygiene Specialists***
- ***Unaccredited Occupational Hygiene Personnel***

Further Study and Sources of Information

Occupational health risks in Health Impact Assessment (HIA): their significance relative to general population risks

As summarized in Chapter D on epidemiology much of what we know about the adverse effects of environmental factors on humans is derived from our workplace experience. When a new material is introduced into commerce, workers are the ones who most likely will be exposed to high levels, day in and day out, over a working lifetime. In effect, as summarized by the report of the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario (Dupre, J. S. et al, 1984): "The asbestos story demonstrates that the process of hazard identification can unravel slowly and that regulatory responses can lag behind the knowledge that slowly accumulates while a mounting toll of disease and death is borne by workers who are thereby cast in the role of human guinea pigs".

In the past workers have unintentionally played the role of the "Mining Canary, with their negative health outcomes serving as a warning for the rest of society. It behooves us to give prominent consideration to these individuals, who are not only responsible for societal productivity, but are most-at-risk, by virtue of the "dose-response relationship" that is fundamental to toxicology.

The chairman of Mansville Corporation, based on that Corporation's extensive litigation experience resulting from worker asbestos exposures, has indicated that their current operating tenets include:

- **activities in Safety and Health are going to be judged in the context of tomorrow's laws, not today's**
- **the ultimate test of professional success, is not whether you keep your company out of court, but the degree of trust between the companies that you work for or consult with, and the employees that you are there to protect.**

[Occup. Haz. Nov. 1992]

We need to remind ourselves that (according to the World Health Organization) "health" is not just to be considered in the negative (as in "absence of disease") but also, as "a state of complete physical, mental and social well-being" (WHO, 1967) not just of the general public but also including those select individuals known as workers. The "casualty" numbers cited for workers are higher in countries where occupational health and safety statutory and regulatory infrastructure is not in place. In other words, in nations that are "developing", or "in transition, a proper consideration of potential impacts on workers (which in that instance, can also include children, for example), as an integral part of the Environmental Impact Assessment (EIA), becomes even more compelling.

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- **the ultimate test of professional success, is not whether you keep your company out of court, but the degree of trust between the companies that you work for or consult with, and the employees that you are there to protect.**

[Occup. Haz. Nov. 1992]

We need to remind ourselves that (according to the World Health Organization) "health" is not just to be considered in the negative (as in "absence of disease") but also, as "a state of complete physical, mental and social well-being" (WHO, 1967) not just of the general public but also including those select individuals known as workers. The "casualty" numbers cited for workers are higher in countries where occupational health and safety statutory and regulatory infrastructure is not in place. In other words, in nations that are "developing", or "in transition, a proper consideration of potential impacts on workers (which in that instance, can also include children, for example), as an integral part of the Environmental Impact Assessment (EIA), becomes even more compelling.

Recent statistics from the U.S. National Institute for Occupational Safety and Health - National Occupational Research Agenda indicate that "Each day, an average of 137 individuals die from work-related diseases and an additional 16 die from injuries on the job.

> **In Vietnam, occupational health is considered to be an integral part of EIA. Statistics from the Viet Nam National Environmental Action Plan indicate the following estimated percentages of workforces suffering from employment-related illnesses: construction - 55%; chemical - 61%; and, metallurgy - 66%.**

Facets of, and Professional Disciplines in, Occupational Health

When conducting an Health Impact Assessment (HIA), it is quite appropriate to attribute considerable weight to the potential impacts of a development on workers, both positive (by improving socio-economic status) and negative. Occupational Health can be a rather expansive concept, and involve diverse workplace parties, including a "joint health and safety committee" (JHSC), off-site therapists, including occupational and physio-therapists, as well as various other clinical specialists, in the case of a need for after-the-fact therapeutic intervention. However, the focus in HIA is the prevention of negative health outcomes in populations, rather than the treatment of impacted workers.

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Occupational / Environmental Hygiene

Industrial Hygiene (IH), as it is still known in some (United States.) circles, originated as a professional discipline in the early part of this century. In the United States, the first national conference on industrial disease was held in 1910, and the first governmental hygiene agencies were established just before World War I.

However, as part of the natural evolution, and with an increasing proportion of workers being found in the service sector industries, the discipline became known as Occupational Hygiene (OH). Indoor air quality (IAQ) in an office or commercial building became as much as issue in the 1980s as had welding fume exposure in the manufacturing sector in the previous decade. Carbon dioxide was developed as a surrogate of human occupancy, to permit a facile appraisal of the adequacy of ventilation from the standpoint of the primary purpose of most buildings. Meanwhile, urea formaldehyde foam insulation (UFFI) in some 80,000 houses across Canada, and a crescendo of concern about asbestos exposures among school children, due to thermal and acoustic insulating materials that had been applied decades earlier, led to a demand for quantitative appraisals of risk, based (in many cases) on an evaluation of the extent of exposure. More recently, mouldy school portables have led to the expenditure of millions of dollars per year, in remediation, by individual school boards. This spread into the non-occupational arena extended the name of the profession (at least for some) to "Environmental Hygiene". However, we will refer to it by its most universally-accepted term of "Occupational Hygiene".

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[1] That is not to say that nursing or medicine is a discipline without proactive attributes, or that there are not practitioners who are very interested in prevention. The reality, however, is that clinicians are largely occupied with the diagnosis and treatment of pathologies that have arisen from adverse exposures, or, in conducting baseline / routine assessments of individuals, to be able to detect early changes; the latter (of course) may be protective to the population in question, even if this is too late for the individual.

In Canada, the 1884 Ontario Act for the Protection of Persons Employed in Factories stated (in part):

> ***Every factory shall be ventilated in such a manner as to render harmless, so far as reasonably practicable, all gases, vapours, dust or other impurities generated in the course of the manufacturing process or handicraft carried on therein that may be injurious to health.***

Amendments in 1932 to the Factory, Shop and Office Buildings Act required employers to report any cases of industrial diseases directly to the Director of Industrial Hygiene.

It is imperative that an accredited occupational hygienist (in the Canadian context, a "Registered Occupational Hygienist" - ROH) be involved in any HIA relating to a substantive project with a job-related element. Other individuals may perform adequately as well, but in the absence of demonstrable professional accreditation, may well not conform to "due diligence" expectations, should there be unanticipated problems in the future. Additional information in this respect is provided in Section 7 of this chapter "Guidelines on the Selection of an Occupational Hygiene Specialist.

The CRBOH accredits (registers) two types of Occupational Hygiene practitioners: Registered occupational Hygienist (ROH) and Registered Hygiene Technologist (ROHT). ROHs are qualified professionals with a University degree in science and a minimum of five years of professional experience. ROHTs are qualified technologists who have a minimum of five years of related experience. Ongoing competency maintenance and development is demonstrated through a formal cyclic re-registration process.

The occupational hygienist is placed in the following context, by Canadian Registration Board of Occupational Hygienists (CRBOH):

- "Occupational Hygiene involves the identification of existing and potential human health hazards in, or arising from, the work place, the evaluation or assessment of the extent of risk posed by the hazards and, the development of effective strategies to eliminate or control the risks.

- Occupational Hygiene draws upon, yet integrates, background disciplines such as biology, chemistry, physics, medicine, engineering, toxicology, etc. In part, it can be regarded as that aspect of the Risk Assessment field which focuses on the interface between workplace-derived hazards and human health consequences. The management of these risks (by means of control programs) is similarly an integral part of the discipline.

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- Occupational Hygiene is a unique, broad and multi-faceted discipline. To illustrate the nature of Occupational Hygiene practice, the following examples of typical functions are provided. These are only examples, and are not intended to be exhaustive, all-inclusive, or exclusive.

Within the definition of Occupational Hygiene, Occupational Hygiene practitioners may typically:

- review projects, designs and purchases to anticipate hazards.
- critically evaluate environments, processes, materials inventories, and worker demographics to recognize potential health risks to persons or communities.
- assess human exposures to hazards through a combination of qualitative and quantitative methods to determine health risks and regulatory compliance.
- recommend effective control measures to mitigate risks via engineering, administrative, or personal protective methods.
- communicate risks and control methods to affected parties including workers, unions, management, clients and/or communities.
- provide education and training about risks and control measures.
- conduct research and development of Occupational Hygiene methods and tools.
- provide academic education and training in Occupational Hygiene.
- develop, implement and audit Occupational Hygiene and related programs.
- manage, supervise or advise Occupational Hygiene personnel.
- coordinate Occupational Hygiene programs with related risk

management efforts, including Safety, Environment and Medicine.

- interface with regulators, communities and professional associations.
- advise on the development of government laws and programs related to Occupational Hygiene.
- provide expert advice in legal and regulatory matters relating to Occupational Hygiene.

- Occupational Hygiene is generally defined as the art and science dedicated to the Anticipation, Recognition, Evaluation, Communication and Control of environmental stressors in, or arising from, the work place that may result in injury, illness, impairment, or affect the well-being of workers and members of the community. These stressors are normally divided into the categories Biological, Chemical, Physical, Ergonomic and Psychosocial.

- The Occupational Hygiene practitioner has comprehensive knowledge of work place chemical factors, and physical factors such as noise and heat stress. In terms of chemical factors, they also have knowledge of safety concepts (e.g. flammability, water reactivity, etc.). They are familiar with biological factors and ergonomics (especially in the case of specific environments such as office buildings) but would in many cases work in conjunction with (or, defer to) practitioners with specific expertise in these areas, as well as in health physics, occupational psychology, safety, etc. Accordingly, their knowledge in these areas would normally be more limited.

- The Occupational Hygiene practitioner is concerned with the broader (extra-workplace) environment, for example with respect to workplace discharges to the natural environment. As well, the practitioner has an appreciation of the

differential impacts of toxicants on workers and the general population (e.g. the greater susceptibility of children to lead).

It should be recognized that there may be other jurisdictional / regulatory requirements that overlap with, or even supercede, the HIA. For example, in Ontario, with any new development, there is a requirement for the proponent to conduct a pre-development review; this must be signed off by a PEng (at present, regulation under review).

Occupational Hygiene involves the anticipation, recognition, evaluation communication and control of hazards in, or arising from, the workplace (see Appendix ___, and/or http://www.crboh.ca/OHDefin.htm for a full definition, as provided by the Canadian Registration Board of Occupational Hygienists - CRBOH).

Occupational disease and its prevention; Occupational Exposure Limits (OELs) as a tool

We know that there are many negative health outcomes that have occurred in workers (and in some cases, their families) as a result of excessive workplace exposures (and, improper workplace programmes and/or facilities, such that workplace contaminants are brought home).

In occupational hygiene the environmental factors causing these negative health outcomes tend to be categorized into one or more of:

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In occupational hygiene the environmental factors causing these negative health outcomes tend to be categorized into one or more of:

- Biological (e.g. mold in building ventilation, animal dander, Hepatitis virus)
- Chemical (e.g. welding fume, solvent vapour, flour)
- Ergonomic (e.g. work station and tool design)
- Physical (e.g. noise, vibration, cold stress, radiation)
- Psychosocial (e.g. poor labour relations, shift scheduling, "stress").

Here, we will deal only with the chemical factors, and mainly in terms of quantitative exposure criteria. We want to reduce health risks to an "acceptable" level. Risk, in turn, could be described as: Hazard x Exposure x Susceptibility = Risk

Chemicals are varied in their hazardous properties (e.g. toxic potential), and in the health outcomes that they can cause. These include some "contact" type conditions, such as dermatitis, or corrosive damage. However, by and large within the occupational context, we are concerned with exposure to airborne contaminants, that become inhaled into the lungs. They can either cause lung disease directly, and/or be absorbed into body fluids (e.g. blood) from the lungs and travel elsewhere in the body to cause other health concerns. We are considering potential effects ranging from irritation right through to fatal consequences either in the short or long term.

The prevention of the occurrence of these conditions is based on maintaining personnel exposures to airborne contaminants well below the levels recognized as having the potential to cause disease. This requires the ability to **anticipate** hazards that might occur, to **recognize** existing hazard potential, to **evaluate** the degree of exposure of the personnel (for comparison to accepted standards) and to conceive and implement **control** measures where warranted. In order for these to be effective, we have to **communicate** effectively, the risks to the stakeholders.

The best recognized (and most universally accepted) Occupational Exposure Limits (OELs) are the Threshold Limit Values (TLV®s). These are established by the American Conference of Governmental Industrial Hygienists (ACGIH - www.acgih.org), a private group of professionals from academia and government. Although OELs are sometimes compared to speed limits on the highway, their application and interpretation is considerably more complex than this. Anyone using the TLV®s (or derivatives) in a real-world situation is cautioned to read thoroughly the most recent Policy Statement and Introduction in the TLV® booklet published by the ACGIH at the beginning of every year. As well, if you are applying the TLV®s to particular substances, you are well-advised to read the appropriate section in the Documentation (now in its 6th edition, © 1991 - but as amended by Supplements annually).

It may be helpful to consider several exposure criteria, intended to protect members of the general public and workers, from chronic and acute health effects, as the case may be. These are:

Chronic-community-EHCs (environmental health criteria)
- air emission limits (e.g. point of impeingement - PoI);46.
- ambient air quality standards (AAQS);
- Criteria - drinking water, recreational water, irrigation water, soil, air, etc.;
- tolerable daily intake (TDI) or RfD (reference dose);

Acute-community (spill/discharge)
- AHIA's 1998 emergency response planning guideline (ERPG)
ERPG-1: 1 hour, mild, transient health effects
ERPG-2: 1 hour, no serious or irreversible or escape-impairing effects
ERPG-3: 1 hour, no life-threatening health effects
Acute/Chronic-workplace
- occupational exposure limits (OELs)-airborne, but may also be skin notation

Acute-workplace-airborne only -escape 30 minutes maximum
- Immediately dangerous to life or health (IDLH)

Criterion	Ammonia	Benzene	Chlorine
AAQS			
PoI	5		0.1
ERPG - 1	25	50	1.0
ERPG - 2	200	150	3.0
ERPG - 3	1000	1000	20.0
TLV® - TWA	25	0.5	0.5
TLV® - STEL/C	35	2.5	1.0
IDLH	300	500	10

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The Occupational Exposure Limits (OELs) are not an "ideal" or "target" workplace level, but rather the maximum airborne level of contaminant currently acceptable. In the case of OELs adopted by Regulation, they are legal maxima. Even in situations where exposures are below the OEL, exposures should be reduced to the lowest practical level (where circumstances permit) on a matter of principle. The TLV's (and related regulatory OELs) are subject to change, for a variety of reasons. For example, for many years the TLV for formaldehyde was 1 ppm as a Time-weighted Average (TWA). In 1992, this was changed to a "Ceiling" (C) of 0.3 ppm, largely to reduce the incidence of sensory irritation.

In the case of workplaces that come under federal jurisdiction in Canada (i.e. under part II of the Canada Labour Code - this includes all federal employees, as well as those involved in inter-provincial activities such as banking, telecommunications, trucking, etc.) the TLV's are actually the regulatory OELs (see 10.19(1) of the (Canadian Occupational Safety and Health Regulations (COSHRs)).

Rabbit Lake Uranium Mining: As described in a November 1993 report of the Environmental Assessment Panel, "the panel's consideration of health and safety issues included both community health and worker health and safety". Following a spill at Rabbit Lake in 1989, Cameco (the proponent) implemented a number of measures to promote the health and safety of employees at the Rabbit Lake operation, including:

- **appointment of an environmental and workers' safety committee;**
- **full time personnel in the safety department conducting training, monitoring, etc.;**
- **new employees receiving basic training immediately upon arrival on site;**
- **an occupational health and safety committee for each of two shifts; and,**
- **an Atomic Energy Control Board (AECB)-approved Code of Practice for radiation protection.**

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individual Occupational Exposure Limits (EOLs) generally assume that exposure is occurring only by the airborne route and by only one substance. Where there is extensive skin contact (particularly for those substances that have a "skin" notation) keeping airborne levels below the OEL may well not be sufficiently protective. With the typical concurrent exposure to multiple toxicants, the consideration of (and mathematical adjustment for) additive or synergistic relationships between the contaminants is also subject to interpretation and (professional) judgment. For further consideration of these points, see, e.g. Risk Assessment: Totally Exposed. OHS Canada 12(4):56-57 (1996); Skin: The Final Frontier. OHS Canada 13(3): 38-40. (1997); Quicksilver, Slow Death - Mercury Poisoning. OHS Canada 14(2): 54- (1998); also visit web site http://www.ohscanada.com/homeset/articles/skin.html.

It may be helpful, to consider several exposure criteria, intended to protect members of the general public and workers, from chronic and acute health effects, as the case may be.

In the field of environmental / health protection, it is customary (e.g. as mandated by various regulations and departmental policies) to dichotomize toxicants into "threshold" and "non-threshold" types. The latter category includes genotoxic carcinogens and mutagens, which are regarded by some authorities as presenting some element of increased risk (say, in accordance with a "linear" dose-response model) no matter how low the dose. The alternative, is to invoke the concept and principle of physiologically-based threshold, and/or *de minimis* risk.

The TLV®s designate by "A" codes, those substances that they have categorized as to workplace carcinogenicity. These are numbered 1 - 5, from "Confirmed Human Carcinogen" through to "Not Suspected as a Human Carcinogen." Under Canada's Workplace Hazardous Materials Information Systems (WHMIS) legislation, a material is a workplace carcinogen if so deemed by American Conference of Governmental Industrial Hygienists (ACGIH) and/or International Agency for Research on Cancer (IARC)[visit www.iarc.fr]

Prospective occupational hygiene applied to HIA - tools and techniques

In order to apply the principles of occupational hygiene (i.e. workplace risk assessment) to HIA, there are various items that should be "assembled":

- clearly articulated and written statement of goals, and an identification of the standard(s) that will be assigned for the purpose of evaluation. In other words, will the goal be the preservation of worker health (as per the WHO definition?), or, simply compliance with statutory requirements?
- layout of the plant, identifying the location of the various processes, and other factors of significance to hygiene considerations (e.g. locations of operable windows, doors, etc.); names of the processes and equipment as they are intended to be used in the plant.
- description / schematic of process flow; chemicals inventory, by process.
- documentation of previous hygiene work that may have been conducted at predecessor / sister plants: air-sampling data, government reports, etc.; specifications for the local exhaust ventilation (LEV) system and other control methodologies.
- record of summarized health / disease data (e.g. incidence of back injury in Department X); Joint Health and Safety Commity minutes, or other documentation of concerns / complaints / symptoms, as above.
- a review of the scientific and professional literature, both text-based and "web"-based, for reports of detrimental effects associated with the materials and processes in question.

There will be a need to understand the intended facility as well as possible (both in terms of structure and function) and to use professional judgement, based on the available information, as to the likelihood of adverse effects occurring.

The process of anticipating impacts parallets that for ecosystem or broader environmental health impact assessment. But, we are dealing with a more clearly defined and more highly exposed population, operating in an environment that is inherently more controllable than the outdoor one. Where the type of facility in question has already been established and is operating elsewhere, the "borrowing" of exposure data from them (which may be possible as a professional courtesy, even between representatives of companies that are commercial competitors on a different level) can be very effective at anticipating and preventing contamination problems.

Mathematical and/or physical modelling may be useful, particularly, in cases where there are adequate data. As well, there are many desirable design characteristics presented in standard reference materials such as in the American Conference of Governmental Hygienists (ACGIH) Industrial Ventilation - Handbook of Recommended Practice.

Pitfalls of occupational hygiene in HIA

The pitfalls are associated with uncertainty, as in all Health Impact Assessments. There is a need to collect data; it may be unavailable, or old, or prepared by individuals with the lack of the necessary knowledge and insight.

Similarly, there is a need to use professional judgement. Although there is accreditation of the professional occupational hygienist by the CROH in Canada, there are only a few hundred ROHs in Canada.

Differences of opinions and approaches to occupational hygiene often reflect academic backgrounds: physicians referr to traditional diseases and public health inspections (sanitary chemistry, sanitary microbiology, water chemistry), while scientists refer to drinking water quality, air pollution, noise pollution and socioeconomic conditions.

A TWA is simply the "average" exposure over the working day. The TWA numerical limits that are listed assume that there is an 8 hour exposure. If worker exposure occurs over a longer period and/or there isn't a 16 hour period between exposures, then adjustments may have to be made to these values from a legal standpointand /or to conform to fundamental toxicological principles. It's amazing how many industrial sites "overlook" this factor.

In addition to the TWA, there may be specific "short term" exposure (e.g. STEL) and "ceiling" (C) limits. The intent may be either to limit irritative effects, acute systemic health effects, and/or the ability of peak exposures to overwhelm the body's defence mechanisms. The ACGIH also have "generic" excursion limit rules: worker exposures may exceed 3 times the TWA for no more than 30 minutes in any work day, and may not exceed 5 times the TWA at any time (effectively a 'default' ceiling).

Guidelines on the Selection of an Occupational Hygiene Specialist:

These guidelines describe personnel accreditation standards that exist in the occupational hygiene field, to assist the employer with the effective selection of appropriate specialist

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These guidelines describe personnel accreditation standards that exist in the occupational hygiene field, to assist the employer with the effective selection of appropriate specialist personnel. They may be useful in considerations both for staff positions, and in the case of project-specific third-party contractors ("consultants"). It is recognized that, as generic guidelines, they are more likely to be generally applied to the latter, and that is their primary intent. In the case of a staff position, the employer may have more need and leisure to consider the nature of individual candidates, and the likely ramifications of requiring specific qualifications, or not.

The occupational hygiene capabilities of industry (as well as commercial or institutional workplaces), and the quality of work undertaken within the realm of occupational hygiene, are key to the prevention of diseases, disabilities and discomforts of workplace origin. The failure to achieve this is tied to substantial potential liabilities.

Currently, Ministry of Labour (MoL) field hygienists are focusing on the core business of that ministry - in their case, enforcement of standards. They no longer provide hygiene services to the workplace, but would expect employer self-reliance, with emphasis on the internal responsibility system (IRS). As a result, many employers may well need to seek specialist services provided by safe workplace associations, health clinics or private service providers.

This document is intended to provide workplace parties with background and guidance in selecting occupational hygiene assistance.

The Need

Employers are expected to address diverse hazards, under occupational health and safety (OH&S) legislation. The OH&S Act requires that an employer "acquaint a worker ... with any hazard in the work", and specifically with respect to biological, chemical and physical agents.

The Regulation respecting control (for example) requires that employers take "all measures reasonably necessary in the circumstances to protect workers from exposure", and specifically, to maintain exposures within the prescribed limits.

Clearly, fulfilling these responsibilities carries with it specialized administrative, professional and technical abilities that are not all within the skill set of the typical employer or workplace. Some of the professional specialties that are necessary in order to have healthy and safe workplaces are defined in provincial statute, for instance, architects, engineers and doctors. Others are clearly established by licensing provisions (e.g. electricians). However, the various specialists who function in the OH&S field, and are integral to a comprehensive and effective health and safety programme, namely, in safety, ergonomics and hygiene, are not defined.

In selecting an individual to perform a role in occupational hygiene, the employer is bound by "due diligence" considerations and "general duty" provisions. In the case of someone who is also appointed to a supervisory position, the onus rests with the employer that this be a "competent person".

What are the consequences if the employer selects someone who does not have the knowledge and skill sets necessary to provide occupational hygiene services for the matter at hand, and the work is done in a manner that places one or more workers at risk? Not only may the worker(s) experience adverse consequences, but the employer faces a liability under the OH&S Act. Conversely, less qualified hygienists may compensate for their uncertainty in making a judgement call by inflating the safety factors inherent in their recommendation(s), thereby resulting in unnecessary cost to the employer.

Ministry of Labour (MoL) staff may be better able to accept a report of work performed by qualified personnel, based on some confidence that it was apparently conducted in accordance with "generally accepted standards of occupational hygiene practice". Thus, ensuring that the work is done appropriately initially, means that it would not have to be repeated, at additional cost.

Accordingly, it is in everyone's best interests if those performing occupational hygiene functions are before-the-fact demonstrably qualified, based on a review by a recognized Board (see below). Occupational hygiene service providers should also be members of a professional association that maintains standards of competence, and provides for the accountability of its members e.g. sanctions in the case of disregard for the code of ethical conduct.

Meeting the Need

To determine if you require occupational hygiene expertise, consider questions such as:

- Is your potential need based on a MoL order; if so, did they advise or specify what type of consultant you should seek?
- Do you require assistance with some aspect of the work environment as it relates to worker health?
- Are you interested in determining the likelihood that a particular job or work area will lead to a health problem?
- Do you have workers who are experiencing vague or specific health effects, or who have particular concerns regarding the healthiness of their work environment?
- Do you wish to determine the airborne level of a specific contaminant under certain work conditions?

An affirmative answer to any of these would suggest that you need someone with expertise in occupational hygiene.

This could be a hygienist or technologist, and either accredited by a recognized hygiene board, or not. When should it be a hygienist? A distinction could be made on the basis of the need for "professional judgement", depth of knowledge, problem solving ability, integrative and communication skills and, holistic programmes, involving multi-disciplinary considerations. Collection and computation of data are commonly considered to be technical functions, whereas interpretation and recommendations on their basis are considered to be professional functions.

Depending on the complexity of the situation, you may need to draw upon specific expertise in disciplines such as ergonomics, health physics or microbiology. This may be provided by hygiene practitioners with specialized skills or, the hygienist may recommend the involvement of personnel dedicated to that particular field. Similarly, the hygienist may advise you to involve a physician, nurse, epidemiologist or engineer, in their area of expertise.

Accredited Occupational Hygiene Specialists

Accreditation is a recognition of an individual's knowledge and ability in a wide range of occupational hygiene skills. Any one accredited individual is not necessarily the most knowledgeable or capable candidate for a particular position or project. Other important criteria in selecting a suitable candidate are not dispensed with by accreditation: knowledge of a specific industry, process or work site; professional referrals from colleagues; a formal statement of qualifications; written proposals to perform designated work in a specified manner.

By selecting an accredited occupational hygienist, assuming that you have verified that other characteristics of the individual are acceptable, you are protecting yourself, the company, the workers and society at large. You have accepted the decision of a professional association, that has pre-qualified someone who has demonstrated the requisite characteristics to be designated as an accredited occupational hygienist. However, you still have to satisfy yourself that this individual has the capabilities to meet your particular needs with respect to timelines, corporate and worker interface, comprehensiveness of project and product, integrity by reputation, etc. as you would for any consultant or contract employee.

There are two generally-recognized North American hygiene accreditations, those offered by the Canadian (CRBOH[2]) and the American (ABIH[3]) Boards. Information / rosters for each of these will be found on their respective web sites:

- http://www.CRBOH.ca
- http://www.ABIH.org

Accreditation is awarded to hygienists on the basis of successfully meeting educational, professional experience and examination criteria. The fundamental requirements of the two Boards are similar.

The CRBOH and ABIH/BCSP[4] also offer accreditation of technologists, with the designations "ROHT" ("Registered Occupational Hygiene Technologist") and "OHST" (Occupational Health and Safety Technologist), respectively. Here again, these are individuals who have been evaluated by a professional association and have been granted their designation in accordance with the criteria of the respective Board.

Unaccredited Occupational Hygiene Personnel

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[2] Canadian Registration Board of Occupational Hygienists, which offers services in English and French

[3] American Board of Industrial Hygiene

[4] Board of Certified Safety Professionals

Anyone may call themselves an "occupational hygienist"; there is no legal protection of the use of the term. Consultant directories, as published by the Occupational Hygiene Association of Ontario (OHAO - Tel: 905 567 7196) and the American Industrial Hygiene Association (AIHA -Tel: 703 849 8888) include some of those who offer services in occupational hygiene; these may or may not be accredited individuals. Unaccredited personnel may be quite competent; you may, in fact, find an unaccredited specialist who is more qualified by experience with respect to your specific needs than a typical accredited specialist. Just as with accredited hygienists, a formal reference may be useful. Errors and omissions insurance may also be considered a positive attribute. However, if you choose to use the services of unaccredited personnel, the onus is on you to determine the suitability of their hygiene-specific credentials and capabilities.

Accordingly, occupational hygiene projects in which accreditation is thought to be particularly compelling, have been listed below.

Does the occupational hygiene work involve, or is it being initiated as a result of:

☐ the laying of charges

☐ a Ministry of Labour order (or other deficiency, noted)

☐ a prescribed assessment

☐ a health-based formal work refusal

☐ other questions of compliance, or matters that may end up in litigation

☐ testimony as an expert

☐ a facility audit (or project, design, process or purchase review) requiring anticipation and/or recognition of health hazards, and/or leading to

☐ identification of critical / likely contaminants and significant exposure scenarios (i.e.

risk assessment)

☐ exposure to new, developmental or poorly characterized environments and/or contaminants (e.g. those without a regulatory exposure limit)

☐ concurrent exposure to multiple contaminants, or involving multiple media

☐ (potential) exposure to serious contaminants with irreversible effects such as carcinogens, mutagens, reproductive toxicants, sensitizers

☐ exposure that shows significant (e.g. more than 10-fold) temporal and/or spatial variability

☐ a situation in which health effects are occurring, or symptoms are being reported

☐ an evaluation pursuant to a workers' compensation claim

☐ development of a control programme:
  ☐ hearing conservation
  ☐ respiratory protection, or other Personal Protective Equipment
  ☐ designated substances

☐ a multi-professional (physician, engineer, etc) undertaking

☐ development of an occupational hygiene training programme

☐ auditing an existing occupational hygiene programme.

If so, it would be particularly advantageous to engage the services of an accredited occupational hygienist, to maximize the protection of all concerned. Selecting an accredited individual provides the employer with a measure of assurance based on the recognized Board's certification and maintenance protocols.

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Texts

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Web site addresses (URLs)

Health Canada:	http://www.hwc.ca/search/iaquery
Ontario Ministries:	http://www.gov.on.ca
Labour:	http://www.gov.on.ca/LAB/main.html

Integrated Risk Information System (IRIS), prepared and maintained by U.S. EPA; electronic data base containing information on human health effects that may result from exposure to various chemicals in the environment. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences.

http://www.epa.gov/ngispgm3/iris

NIOSH Home Page http://www.cdc.gov/niosh/homepage.html

Mining Health and Safety Research - Pittsburgh and Spokane Research Centres (NIOSH)

http://www.usbm.gov/

Coal Mining Photo Series http://www.-busph.bu.edu/Gallery/Gallery-Lobby.nclk

IARC: http://www.iarc.fr/

World Health Organization http://www.who.ch/

Implementing an Environmental Management System (ISO 14 000)

http://www.ait.ac.th/AIT/som/as/ISO14k/welcome.htm

Dieselnet http://www.dieselnet.com/

Resources and information about Environmental and Occupational Health; hundreds of files from the University of Edinburgh

http://www.med.ed.ac.uk/hew/

Occupational and Environmental Medicine WWW Resource Index (external links from the OEM/Duke pages)

http://gilligan.mc.duke.edu/oem/index2.htm

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CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 3

Roles for the Health Practitioner

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DECEMBER 1999

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Part 9 of 9

The Contribution of Economics to the Environmental Valuation Process

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Introduction

For several of the players involved in impact studies, the environment must be taken into account not only through its natural dimension, but its economic and social dimensions as well. Thus, the update of the World Bank's environmental assessment guidelines (July 1997) cites the need to take into account the economic value of impacts on human health. This is not really new—the same requirements to take into account the monetary aspects of the environment and natural resources having been documented in impact studies for a number of years (not that this has led to any real change in practices…).

The interest in monetary valuation can be explained by a number of factors. First, failure to assess the value of the environment is often tantamount to attaching zero value to it and thus contributes to inadequate management. Monetary valuation can help inform the decision-making process at both the project assessment and policy levels (see Box 1). Environmental valuation also presents some interesting perspectives in terms of developing a set of indicators aimed at raising the awareness of decision makers and the population as a whole (see Box 2). Lastly, the whole issue of compensation valuation from a legal standpoint also constitutes an important factor in developing these valuation methodologies.

The present study is an introduction to monetary valuation of environmental impacts. The first section briefly describes the principles of monetary valuation, followed by the various sources of economic value and lastly the main methodologies used to assess these benefits. The second section examines the question of decision-making tools and the role of monetary valuation in decision making. Although our study explores the valuation of benefits associated with the environment in a general way, special attention is paid to human health issues.

Monetary Valuation of Environmental Benefits

Basic principle of monetary valuation

According to economic theory, price is an initial indication of a good's usefulness, or, if you will, a measurement of the benefit it procures for the person consuming it. This approach is by no means new. As early as 1853, Dupuit argued that [TRANSLATION] "usefulness is what establishes value; the monetary sacrifice made by the transactor is what measures usefulness" (Garrabé, 1994). However, since many environmental goods do not have a market value, individuals cannot reveal their preferences for these goods through the price mechanism—hence the interest in seeking to determine the maximum sum that the consumer would have consented to pay for this item had such a market existed.

Viewed from this perspective, the economic valuation of environmental benefits is based on two central hypotheses of welfare economics which place the individual at the heart of the valuation procedure:

- individual preferences are the basis of benefits valuation;
- individuals are the best judges of their preferences (Desaigues and Point, 1993).

These preferences manifest themselves on a market (real or fictional) and are expressed in the form of an individual's willingness to pay (WTP), graphically represented by the demand curve. The benefit procured by the consumption of a quantity x of a particular good corresponds to the surface below the demand curve, namely the summation of expenditures made and the consumer's surplus (Figure 1). This surplus is the maximum amount that individuals are prepared and able to pay, over and above what they have already paid, to continue to benefit from or use this good. In the case of an environmental good with no market value, the expenditure is zero,

therefore, but the economic value is not necessarily zero, since the economic benefit associated with this good corresponds to the consumer's surplus. This surplus, or WTP, can be measured by various techniques of monetary valuation (see section - Monetary valuation techniques). But before applying these techniques, one must first be able to identify the various sources of benefits associated with this good.

Figure 1: Total benefit

redo figure 1

Components of the economic value of the environment

The value of the environment can initially be associated with the benefits flowing from the direct and personal use of the environment. But the benefits associated with future (even optional) use, as well as the value attached to the environment in the absence of direct use, either present or future, also help define the value of the environment. The notion of "total economic value" (Pearce et al., 1989) illustrates this broadened concept of value by comprising a wide range of motivation, including use value, either present or future, and non-use value (Figure 2).

Use value comprises all personal benefits flowing from the present use of a resource, whether this use is recreational, commercial or traditional. This could involve extractive activities, such as fishing, hunting or water consumption, and non-extractive activities, such as hiking or observation.

Indirect-use value refers to the benefits generated by the various ecological functions—hence its indirect and, above all, exclusive use nature. This value is based on ecosystems' capacity to generate and support life, assimilate and transform waste and produce the energy and materials used in the manufacturing process.

Option value is defined as the willingness to pay for an environmental good in order to preserve the possibility of continuing to enjoy it. What this entails, therefore, is preserving the environment with a view to its probable use in the future.

The notion of non-use value is divided into two categories. The first refers to heritage value, or the willingness to preserve the environment as a heritage to be handed down to future generations. The second value source, existence, can be defined as the economic value that people attach to the fact that they know that the resource exists in nature. The heightened importance of this value is reflected by the legal recognition afforded it by the United States Court of Appeal in 1989, to the extent, however, that this concept is "seriously measured" (Arrow et al., 1993).

The relevance of this concept of "total economic value" in describing the benefits flowing from the environment is the object of a fairly broad consensus in the literature. It should be pointed out, however, that the exact definition and scope of each of these value sources is subject to considerable discussion, particularly in terms of non-use value. What's more, it is often the case that these various value sources can only be assessed in an aggregated manner because of the complementary or substitutable relationships among the various benefits sources.

Figure 2: The various sources of economic value

to be inserted

Source: Adapted from Munasinghe, 1992

Monetary valuation techniques

To be able to apply the relationship between value and "willingness to pay" to environmental goods which are not transacted on an actual market, one must develop procedures for revealing this willingness to pay. In the last 50 or so years, a number of techniques have been developed to assess this willingness to pay in a variety of circumstances.

The methods described in this section are grouped according to the classification adopted by the OECD (1995), to wit: the *methods for monetary valuation of physical effects*, the *revealed preference methods* and the *contingent valuation methods*. The first methods associate a price, directly measurable on a market, with the physical change in an environmental good or service. The second methods are used to deduce the market value with the help of prices which are indirectly associated with this good. Lastly, the contingent valuation method (CVM), is used to construct a fictional market where individual preferences can be expressed in the form of willingness to pay.

Some of these methods are commonly used for the monetary valuation of impacts on health; specifically, that is the case for human capital, contingent valuation and protection expenditure valuation methods (OECD, 1995). The expanded notion of environmental health can lead analysts, however, to focus on several types of benefits and can require the use of different valuation methods. Thus, our study describes valuation methods covering a relatively wide spectrum of benefits.

Monetary valuation of physical effects

The most direct method of evaluating environmental changes consists in associating the physical changes occurring during the period in question with the market price of these goods or services. Establishing the dose-effect relationship is central to this process, but this causal relationship is sometimes difficult to determine. According to the good being analysed, different methods can be used:

➢ Damage functions

Damage functions initially require a study of the physical relationships between a pollutant's *doses* and its *effects* on the productivity of natural environments. The economic value of this damage is then evaluated by assessing the market value of this production variance. The same type of approach can be used in considering the maintenance costs required to compensate for the damage to material goods.

This approach is commonly used because it refers directly to market price. The process can be used, for example, to measure in economic terms the effect of air pollution on crop yields or building dilapidation.

Ø Replacement cost method

At first glance, this method appears relatively simple. The idea is to determine the physical damage, and then to assess the costs required to restore the degraded environment. The approach gets complicated, however, when the time comes to determine the desired level of restoration (must the environment be restored to its initial state or to an "acceptable" state?). Also, the restoration must be feasible. The approach is impractical, therefore, in the case of irreversible loss.

➢ Human capital method

The traditional approach to the valuation of human life is that of "human capital". To begin with, a dose-effect-type relationship must be established between environmental changes and the resultant variance of the mortality or morbidity risks. The valuation of the losses in human life, or in days of incapacity, is then

transposed in economic terms by using, as a value of these losses, the discounted flows of lost income as well as the processing costs. The value of human life is thus reduced to its only productive aspect, which raises a serious question of ethics: the life of someone with a lower income expectancy possesses less value.

Revealed preference method

In cases where environmental goods do not possess any market value, various methods can be used to assess individuals' preferences on the basis of behaviours observed on markets that are complementary or alternative to the environmental market. These methods assess economic value by referring to an actual expenditure, thus limiting the sources of bias in the valuation. These methods can be used to assess use values only, however.

- Transportation cost method

The transportation cost method seeks to measure the value of the consumer's surplus associated with a particular site, on the basis of the expenditures incurred to travel from home to the site. Studies using this technique, which has been recommended since 1979 by the Water Resources Council for project assessments, now number in the hundreds in the United States.

The initial approach used in the 1960s was relatively simple. By estimating the average transportation cost for individuals hailing from the same region and by increasing this transportation cost with the help of a mock toll, one can determine the effect of this new cost on the visitation rate. By increasing this mock price so

high that the number of visitors is nil, one obtains the total number of visitors for each possible price level. Once this demand function has been obtained, one can infer the consumer's surplus.

The transportation cost variable cannot in and of itself explain, however, the visitation rate for a given site. The analytical technique has been considerably refined since the first analyses, therefore; now it is possible to take into account other variables explaining the visitation rate, such as user preferences, user income, the features of the site, the presence of alternate sites, etc. The equation describing the visitation rate can therefore take a far more detailed form, which will then serve as a basis for evaluating the surplus.

Although this method is widely used, it poses a number of practical difficulties associated with, among other things, determining the transportation cost. Thus, the time opportunity cost, consideration of the costs associated with the purchase of durables used for the activity, accommodation and living expenses associated with the travel, the portion attributed to the site being studied in multi-site trips, delineation of the alternate sites and, lastly, characterization of the environmental benefits all entail discretionary choices.

- Hedonic approach

This approach seeks to identify the relationship between the value of a market good and certain environmental quality indicators, and then to infer from this relationship a monetary value with environmental characteristics. This methodology is particularly well adapted to studying the real estate market, where one can easily see how the value of two identical residences will differ if

they are located in a physical environment possessing significantly different characteristics. However, since the price of this real estate can be explained by a host of variables, the choice of these variables will be determinant; too few independent variables will not allow an accurate valuation of the contribution by environmental factors, and too many can lead to correlation biases.

In practice, this approach requires reams of data and a relatively awkward statistical analysis. Furthermore, the real estate market must function the way it is supposed to and the environmental characteristics must be clearly perceived and evaluated by the owners. These constraints limit the use of this method to large-scale studies on the impact of air pollution (a classic example: the noise produced by airplanes).

- Protection expenditures

When there is a change in the quality of the environment, individuals can try to protect themselves against this deterioration through various expenditures, such as installing water filters or purification devices and taking measures to combat erosion. Assessing these expenditures provides an initial valuation of individuals' preferences.

This method is relatively simple and has the advantage of being based on observed behaviour. Environmental expenditures must not be confused with environmental costs, however; otherwise, a portion of the information is perceived as the entire impact on the environment. Moreover, the alternatives remain imperfect and the hypothesis that people know the scope of the risks to which they are exposed is not necessarily verified.

Contingent method

Developed in the 1950s, the contingent valuation method has been significantly upgraded over the past few years, and the number of valuations has risen sharply, particularly in the United States. This is attributable to the fact that this method can be applied to any circumstance and, above all, that it is the only valuation technique that allows us to measure economic value in its entirety, including non-use value.

The principle underlying this technique is relatively straightforward. In a normal market, paying a certain amount of money for a particular good reveals the economic value that individuals attach to this good, within the confines of their budget. The contingent valuation method seeks to imitate this scenario through a survey, whereby individuals reveal their willingness to pay for these environmental goods in a hypothetical market.

Basically, the survey can be divided into three sections: a physical description of the good to be assessed and any potential modifications being contemplated; one or more questions aimed at determining maximum willingness to pay to obtain the improvement or avoid the deterioration in question[1]; and a series of questions in order to describe the respondent's socio-economic characteristics with a view to constructing an explanatory model for WTP.

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[1] In cases where individuals are confronted with a loss of an environmental good for which they feel they hold the rights, they will claim compensation, and one will talk in terms of "willingness to receive". In practice, however, the consensus

While the process seems relatively simple, the hypothetical nature associated with the absence of actual payment and the many biases that can result have given rise to a large body of literature. These biases involve, among other things, the respondents being led to deliberately distort their responses, the presence of implicit values in the questionnaire, scenarios which incorrectly describe the good being assessed and problems having to do with benefit aggregation and sampling (Mitchell and Carson, 1989).

It should be pointed out, however, that the validity of this method, particularly in terms of the appraisal of non-use value, was the focus of discussions by the US National Oceanic and Atmospheric Administration panel of experts. The panel concluded that [TRANSLATION] "under certain conditions[2], contingent valuation studies provide useful information... [which is] sufficiently reliable to serve as the starting point for a legal process of assessing damages, including for loss of existence values" (Arrow et al., 1993).

Value transfer

Having the methodological tools necessary to measure the various sources of benefits does not mean that these valuations can be conducted for decision making. The information cost can be relatively high, and the time needed to design and execute the process can be excessive. These constraints have led to *value transfers*, the use of values obtained in an analogous context but in another place and time.

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surrounding the appropriateness of measuring willingness to pay is almost unanimous.

[2] It is recommended that the respondents be well informed of the damage to be assessed and of the available substitutes; the means of payment must be clearly presented, with an emphasis on budgetary constraints; the referendum approach should be used, and a WTP-type approach should be used instead of a WTR-type approach.

The US Administration recommends taking into account three criteria to ensure that the value transfer is credible:

- the users and natural resources (or environmental services) examined during the initial study must be comparable to those of the situation being studied;
- the changes in quality or in the quality of the natural resources (or environmental services) examined during the initial study must be comparable to those of the situation being studied;
- the initial study must be a quality exercise (NOAA, 1996).

Desaigues and Point (1993) add that the property rights must be identical, and that it is always preferable to transfer the demand function and then determine willingness to pay rather than directly transferring the value of the willingness to pay.

With a view to facilitating these value transfers, Environment Canada has developed an automated database containing several hundred studies. Box 3 describes in greater detail this *Environmental Valuation Reference Inventory.*

The specific case of mortality and morbidity assessment

As mentioned previously, the traditional approach to economic valuation of human life is that of human capital. Beginning in the 1970s, another approach has found its way into the literature, that of "willingness to pay". However, since one cannot measure willingness to pay in order to preserve life (an infinite value, obviously), willingness to pay is measured instead to modify probability of death. This takes the form of the maximum amount individuals are prepared and able to pay so that an undertaking resulting in a reduction of mortality or morbidity risks can take shape. The reverse is also true, since one can measure the minimum amount that individuals demand to receive to accept an increase in risk.

How then does one determine this willingness to pay (or receive)? Two approaches appear in the literature: the hedonic approach and the contingent approach.

The former is based on direct observations of behaviour when money changes hands, implicitly or explicitly, in consideration of a change in risk level. Thus, studying the impact of risks on salaries allows one to determine the premiums paid in higher-risk sectors. This approach is not without its difficulties, however. First, the labour market does not necessarily function perfectly, which can produce situations in which individuals are unable to obtain fair compensation despite the change in risk level. Second, there can be a *selection bias*—persons accepting jobs posing the highest risk are likely unrepresentative of the population. Lastly, the valuation is based on the change in risk perceived by the individual, which is not necessarily consistent with the actual change (Lanoie, 1993).

The contingent approach is used to create a mock market and directly assess willingness to pay (or receive) when there is a change in risk level. This approach presents a number of advantages: direct possession of the information being sought; the sampling procedure ensures the representativeness of the group selected; and certain segments of the population—those most affected by the undertaking—can be targeted. On the other hand, this method raises the whole question of the potential construction of the value by the questionnaire and the many biases that can be present in this type of valuation. Moreover, certain authors doubt the appropriateness of having the general public assess questions involving probability variations.

Lanoie (1993) has identified 37 studies on human life, 22 of which use the hedonic approach. Of the 37, he has chosen 21 which he considers to be more reliable; armed with these, he estimates the value of a statistical life to be in the order of C$5.6 million (1991 dollars). The author concludes, however, that in practice, analysts and decision makers refer more to the human capital approach, and thus to the "cost of losses of human lives" rather than the value of human life.

Undeniably, however, the question of attaching monetary value to human life makes some people feel uncomfortable. The question is even more delicate when the valuation focuses on an international issue and involves developing countries. The report by the Intergovernmental Panel on Climate Change notes that [TRANSLATION] "there are few studies for the developing world, and it is difficult to say what the results would be using these techniques. To the extent that willingness to pay is conditioned by individuals' capacity to pay, the results might be far lower. A preliminary study for India estimates "personal valuations" at around $120,000" (IPCC, 1996).

Box 1: Monetary valuation of the benefits flowing from the Clean Air Act

The EPA recently published a comprehensive monetary valuation of the benefits stemming from the implementation of the Clean Air Act (CAA) for the period 1970-1990 (EPA, 1997). This study is an interesting example of an assessment of the benefits of an environmental policy in which the valuation of the components associated with human health occupies an important place.

The approach used seeks to evaluate the benefits and costs of two alternate scenarios: the first describing the actual implementation of the CAA from 1970 to 1990, the second reflecting a hypothetical situation where no air pollution control program is put in place during this period.

First, the direct costs associated with the CAA from 1970 to 1990 were assessed at $523 billion (1990 US dollars). These expenditures allowed a significant reduction in polluting emissions in relation to the "non-control" scenario, to wit: around 30% fewer emissions of nitrous oxide, 40% for sulfur dioxide, 45% for volatile organic compounds, 50% for carbon monoxide, 75% for particles and 99% for lead. It should be pointed out, however, that depending on the pollutant, this emissions reduction does not necessarily lead to a corresponding level of improvement in air quality.

Next, the air quality improvement resulting from this reduction in emissions was associated with a series of benefits from the standpoint of human health, welfare and ecological systems. Where the state of knowledge permitted, the importance of the benefits was quantified using various functions appearing in the literature. In particular, that was the case of the effects of several pollutants on human mortality and morbidity, the effects of exposure to lead in children's cognitive development and the effects of air pollutants on agricultural productivity. Benefits for which a quantified estimate of the dose-effect relationship is not available are not included in this cost/benefit analysis. Thus, the main sources of the benefits flowing from the CAA can be associated with a lower incidence of mortality caused by suspended particulates and lead, lower incidence of chronic bronchitis caused by particulates, a positive impact on the cognitive development of children exposed to lead, a lower incidence of respiratory problems caused by particulates, ozone, nitrous oxide and sulfur dioxide, a lower incidence of hypertension caused by lead and fewer hospital admissions caused by particulates.

Since the value of each of these avoided risks does not exist on a market, it was inferred with the help of various monetary valuation techniques. Thus, contingent analysis was used to assess chronic bronchitis and respiratory problems; the protection expenditure approach was used to measure hypertension and hospital admissions; as for the impact of lead on children, the valuation was obtained by considering the decline in expected income and the increase in social spending, for lack of a better estimate; the mortality risk valuation was based on the results of 26 studies, of which 5 used contingent analysis and 21 used hedonic analysis of the labour market. On the whole, the benefits associated with the CAA during the period 1970 to 1990 were assessed at between $5.6 and $49.4 billion, with a central value estimated at $22.2 billion (in 1990 US dollars). Compared to the cost of the CAA, the net benefit ranges between $5.1 and $48.9 billion with a central value of $21.7 billion. Clearly, therefore, the CAA makes economic sense, especially since the valuation is underestimated due to the exclusion of several non-monetary benefits. The study also identifies several areas where uncertainty, be it physical or monetary, remains very high and should be the subject of research. But this study also illustrates the difficulties of assessing environmental policy, from both a physical and a monetary standpoint. Thus, certain agencies of the US administration have expressed reservations about several of the report's central hypotheses, specifically: the assessment of the deterioration in air quality between 1970 and 1990 in the absence of the CAA, the methods used to assess the incidence of illness and premature mortality avoided thanks to the CAA, and the methods used to estimate the value that people attach to these avoided risks. We are faced here with the classic criticisms levelled at this approach, namely the assessment of the "dose-effect" relationship and the appropriateness of the monetary valuation techniques used to assess these effects.

Box 2: Monetary valuation of environmental functions

The goods and services produced by ecological systems and stocks of natural capital are essential in maintaining life on earth. They contribute to human welfare, both directly and indirectly, and thus constitute a portion of the planet's total economic value. However, the value of environmental services is not fully taken into account by markets or adequately quantified on a par with economic services; often, therefore, not enough weight is attached to it during decision making. Consequently, it may be useful to determine how a change in the quantity or quality of this natural capital can modify this well-being.

A collective of 13 authors published in *Nature* an overall monetary valuation of 17 services produced by the ecosystems of 16 biomes (Costanza, 1997). The analysis, however, excludes non-renewable resources (fossil energy and minerals) and considers neither the ecosystems' inherent value nor the value that can be attached to the minimal stock needed to maintain ecological balance. Rather, the study assesses how small changes on a large scale or radical changes on a small scale can affect well-being. Using values published in the literature for the various ecological services, the authors estimate the value of all these environmental goods and services at between US$16 and $54 billion a year, with a mean value of US$33 billion. This "minimal" value can be compared to world marketed production of nearly US$18 billion. These results indicate that if there was a desire to replace these environmental services at their marginal value, gross world product would have to be increased by 180% solely to maintain an equivalent level of well-being. Even if this were possible, it would not lead to an improvement in well-being because it would merely replace existing services—ignoring the fact that several of these services are literally irreplaceable.

The authors recognize that there are many empirical and conceptual problems with this type of valuation.

What's more, the argument can also be made that preserving ecosystems is a moral issue. But as far as the authors are concerned, moral questions and economic arguments are not mutually exclusive, and such discussions can and must be carried out in parallel. In this context, the exercise remains useful in attaching a relative value to ecosystems, establishing a preliminary approximation of the scope of these services, identifying elements about which there is little information, and stimulating research and debate. While not contributing directly to decision making, the development of such "macro-indicators" helps raise awareness.

Box 3: Environmental Valuation Reference Inventory (EVRI)

The database set up by Environment Canada, with the support of the EPA, identifies several hundred studies on monetary valuation of environmental goods and services. The merits of this analytical instrument also derive from the fact that it has been constructed in such a way as to allow the selection of the most relevant studies, as judged against a series of criteria such as the various environmental goods and services, geographic characteristics or valuation techniques.

Obviously, the database alone does not allow the entire value transfer procedure to be carried out; what it does, however, is enable analysts to identify more rapidly and at a lower cost the most relevant studies with a view to subsequently carrying out this transfer. In the human health sector, for example, the database provided analysts with access to over a hundred studies in the summer of 1998.

Monetary valuation and decision making

Cost-benefit analysis

All projects, be they private or public, generate costs and benefits. For the individuals or business carrying out a project, a *financial analysis* should enable them to determine the private viability of the project by comparing all the costs and benefits assumed by the proponent. While such an approach can be used to justify a project from a business standpoint, it cannot be used to justify it from a societal perspective.

In environmental terms, the difference between the private viability and social viability of a project can be explained by the presence of externalities—losses of benefits resulting from the production or consumption of a good in the absence of financial compensation. Thus, although a project's proponents must put in place mitigation measures to limit the project's negative impacts, the residual damage to ecosystems or human health is not considered as a cost if responsibility for this damage is not assumed by the proponents (such would be the case, for instance, of the impact of airborne pollutants on human health). The cost-benefit analysis seeks to rectify this shortcoming by comparing the costs and benefits of a project for society as a whole. This shifts the frame of reference from private viability to social viability.

The principle is relatively simple: if the sum of the benefits stemming from a project exceeds the costs (therefore, if the benefits/cost ratio is > 1), the project can be considered as economically justified for society.

The relatively "simple" nature of this decision-making rule explains why this process has become so widespread. The process is not without its complications, however (and on several levels, at that). First, all the monetary costs and damages must be taken into account; this involves having proper valuation procedures in place and addressing the distribution of costs and benefits. Second, since the damages and costs associated with a project are spread over time, they must be *discounted* to take into account time preferences. Third, risks and uncertainty can vary from one project to the next and must be taken into consideration.

- monetary valuation

A large part of the research on cost-benefit analysis has often consisted of an extension of the type of benefits that are quantifiable and measurable in monetary terms. This can be explained by the fact that the analysis is based on an exhaustive compilation of the costs and benefits and that, without a valuation of some of these costs or benefits, doubt could be cast on the conclusions of the analysis. In practice, however, it is rare that all the benefits and costs are taken into account. As we saw in the previous section, several methodologies can be used to assess benefits in their entirety. This valuation of environmental damage (or of benefits, in the event of favourable impacts) is not systematic, however, since scientific knowledge cannot always be used to assess these impacts even in physical terms (see Box 1) and the valuation of individual preferences does not necessarily take into account all the benefits (see section on Cost-effectiveness analysis).

- equitableness

The principle underlying this decision-making rule implies that the benefits are sufficient to offset the costs. However, the CBA does not mean that this compensation between those who reap the benefits and those who must shoulder the costs will be carried out; it simply means that it could be carried out. What's

more, since the analysis does not systematically take into account the distribution of these costs and benefits, one needs to pay special attention to the equitableness of this distribution.

- taking time into account

The need to take time into account stems from the fact that individuals do not attach the same value to costs and benefits that are spread over time. This *time preference* simply reflects the fact that an individual prefers receiving $1000 today to receiving $1000 20 years from now. Moreover, there is an *opportunity cost* of capital, since the same sum can be invested in various projects or simply loaned out at interest.

To compare sums at different points in time, they must be discounted.

$$\text{Discounted value of A} = \frac{A}{(1 + \text{discount rate})^{n}}$$

with n = number of years

This discount rate has given rise to a large body of literature and a great deal of controversy, since it can significantly influence the results of the valuation; thus, the higher the discount rate, the lower the present value of future costs and benefits[3]. If it is conceivable that individuals possess, on an individual basis, a marked preference for time, this preference is surely lower in the case of societies, since they can be considered as quasi-immortal (World Bank, 1991). The discount rate used for CBAs is therefore lower than the opportunity cost of capital and reflects this social time preference.

The decision-making criterion for judging a project's acceptability is therefore the discounted benefits / discounted costs ratio or the difference between the sum of the discounted benefits and the sum of the discounted costs (or the *net present value)*. However, the influence of the discount rate on these values warrants a sensitivity analysis with several rates, with a view to demonstrating the influence of this rate in the end result.

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[3] For example, a sum of $1000 in 20 years has a present value of $148.64 with a rate of 10% and a present value of $672.97 with a rate of 2%.

- risk and uncertainty

Lastly, several environmental impacts are characterized by the uncertainty surrounding them over the long term. However, as we gain more knowledge, we can express our uncertainty in terms of the probability of seeing them occur. This shifts the focus from an uncertainty analysis to a risk analysis. It can therefore be worthwhile to invest in information so as to be able to diminish uncertainty. Decision makers' aversion to risk and uncertainty should also be factored in when analysing the results.

Cost-effectiveness analysis

If the optimization-type approach that characterizes the CBA constitutes a powerful tool to support the decision-making process, it does not necessarily conform to a sustainability logic. Indeed, the methods for assessing the depreciation of non-market natural capital can lead to [TRANSLATION] "confusion between economic optimum and sustainable use of this capital. There is nothing to indicate that the economic optimum corresponds necessarily to the thresholds for use of the latter" (Faucheux and Noël, 1995).

What we are dealing with here is not a simple question of precision in assessing economic value or of the ability to measure the total value of the environment. Apart from this precision, the very principle of optimization implies that one can substitute natural capital and manufactured capital, and that a decline in the benefits generated by the environment can necessarily be offset by economic gains. This is tantamount to denying the existence of any environmental distinctiveness and implying that ecological functions are all substitutable.

Given the uncertainty as to the degree of substitutability and the irreversibility characterizing several environmental issues, *the precaution principle* should lead us to envisage only with the greatest caution any serious or irreversible change in the environment (Godard, 1997). The maintenance of environmental functions can thus be considered as a constraint, and this constraint cannot be defined solely on the basis of economic criteria.

This normative approach, used to determine *a priori* a level of environmental protection, is outlined in Figure 3. The events shown on the right respond to criteria for maximizing individual benefits, since the damage is reversible and minor. The decisions shown at the centre are often taken collectively by the various agencies, and the cost-benefit analysis can also be used as a decision-making support tool. The events shown in the upper left corner are major and irreversible; the decisions relating to these changes are taken according to a process of collective choices, often determined or constrained by legislative decisions. In the latter case, it is necessary to organize information differently and focus on the minimum standard to be preserved and on the most efficient means of implementation.

In this context, although economic valuation of benefits can lead to improved environmental decisions, the economy cannot take the place of collective political decisions for questions of distribution, including resource rights for future generations or within the current generation. For certain types of decisions, the issues of sustainability and ecosystem value ultimately require collective choices via a political process. Decision makers do not need a sophisticated cost-benefit analysis to justify actions that prevent significant and irreversible environmental effects. In these circumstances, an analysis of the efficiency of the various policies or actions to prevent such consequences is sufficient (Bingham et al, 1995).

Victor also points out that questions relating to sustainability of natural heritage [TRANSLATION] "are not questions that can be answered solely from an economic perspective. The answers to these questions are largely social, political and ecological and involve global as well as local considerations" (Victor, 1994). In this context, a case can be made that the question of monetary valuation no longer centres on a measurement of willingness to pay but rather on the sum of the costs of preserving or attaining a defined objective in a multidisciplinary manner. Economics plays a key role in determining the most efficient approach for achieving this objective.

Determining these minimal standards cannot be dissociated, however, from the question of the development outlook which they provide, the compensation which they can necessitate and the financing of these measures. In this context, the contribution of economics to the valuation of environmental impacts is not confined to simply monetary valuation, but also includes an analysis of the policies put in place from the standpoint of efficiency and equity.

Figure 3: Scope of monetary valuation methods

Source: Adapted from Bingham, 1995

To the extent that these answers to the environmental questions are of an ecological, social, political and economic nature (i.e. decidedly multidisciplinary), compromises are necessary between requirements that are sometimes contradictory. Multi-criteria analysis offers a series of methods or procedures which tend to formalize these compromises to a certain extent.

After defining the problem to be dealt with and choosing a series of valuation criteria, either qualitative or quantitative, an aggregation procedure is used to integrate and weigh all these criteria. The appeal of this approach lies, of course, in its ability to take into account quantitative variables, including economic valuation of benefits, and qualitative variables. The procedure leading to decision making is thus not confined to purely economic criteria.

Conclusion

Regardless of one's own views concerning the role the market should play as allocator of resources in society, the corollary of this being the role the State should play, one must not lose sight of the fact that the market is a social construct. It is a tool in the service of society for attaining objectives set by society. Accordingly, it is not for the market to develop conservation priorities, especially when these priorities involve inter- and intra-generational equity (Réveret and Webster, 1997).

As part of an environmental impact study, one should determine, as best one can, the value of the gains and losses associated with the various components of the environment. That said, this variable should not become the only decision-making criterion. In this context, the cost-benefit analysis can be used to inform but not dictate decisions relating to environmental policy, programs and research (EPA, 1997).

While the methodology and reliability of monetary valuation procedures have made significant strides, it seems that the tendency to take into account monetary valuation in the decision-making process, specifically as part of impact studies, is not totally clear as of yet. This is opening up some excellent avenues for research.

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